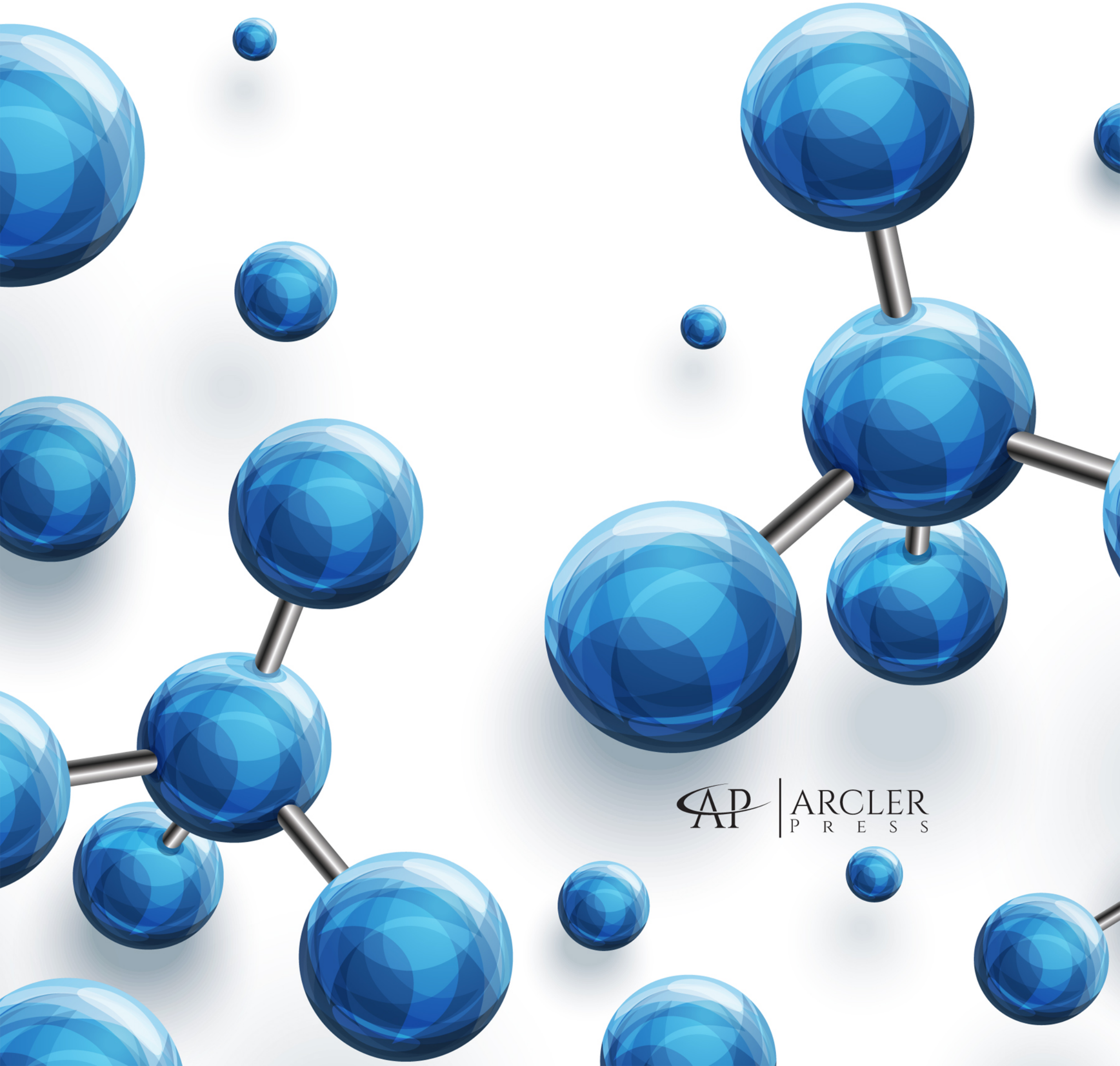
Encyclopedia of Nanotechnology

Edited by:

Saeed Farrokhpay



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ENCYCLOPEDIA OF NANOTECHNOLOGY

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Saeed Farrokhpay

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ABOUT THE EDITOR

Dr Saeed Farrokhpay is a Chemical Engineer with several years of experience in mineral & material processing. He obtained his PhD from University of South Australia in 2005. He is currently a Technical Consultant in Australia. He has worked for more than 20 years at mineral and chemical industries, universities and research centers around the world. Dr Farrokhpay has published more than 90 papers in high ranked journals and conference proceedings. He has also edited several technical and scientific books, and served as an editorial board member of several international scientific journals.

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LIST OF ABBREVIATIONS

ABS	acrylonitrile butadiene styrene
AFM	atomic force microscope
AI	artificial intelligence
AKD	alkylketene dimer
ALD	atomic layer deposition
AMMs	artificial molecular machines
AMS	automated manufacturing system
AT	axial transmissive
CAMs	cell-adhesion molecules
CFRP	carbon fiber reinforced panel
CH_3	trimethylindium
circRNA	circular RNA
CNTs	carbon nanotubes
CT	Czerny–Turner
CVD	chemical vapor deposition
CVT	chemical vapor transport
DNA	deoxyribonucleic acid
DPN	dip-pen nanolithography
DRAM	dynamic random-access memory
DURC	dual-use research of concern
DWNTs	double-walled carbon nanotubes
EcBfr	*E. coli* bacterioferritin
ECM	extracellular matrix
EL	electroluminescence
FDA	Food and Drug Administration
FT	Fourier transform
FTIR	Fourier transform infrared
GAGs	glycosaminoglycans
HFF	human foreskin fibroblasts
HOPG	highly orientated pyrolitic graphite

ICs	integrated circuits
IP	intellectual property
LB	Langmuir-Blodgett
LCOE	levelized cost of power
LCR	ligase chain reaction
LDOS	local density of states
LED	light-emitting diode
LET	lipid encapsulation technology
LHC	large hadron collider
LLPS	liquid-liquid phase separation
LM	Langmuir monolayers
LMU	Ludwig Maximilians University
LOC	lab-on-a-chip
MBE	molecular-beam epitaxy
MEMS	microelectromechanical systems
miRNA	microRNA
MLE	mink lung epithelium
MOCVD	metal-organic chemical vapor deposition
MOSFETs	MOS field-effect transistors
mRNA	messenger RNA
MRS	magnetic resonance spectroscopy
MWCNT	multi-walled carbon nanotube
NC	nanocrystalline
NCAM	nanocapillary array membrane
NEMS	nanoelectromechanical systems
NL	nanolithography
NM	nanometer
NSOM	near-field scanning optical microscope
OLEDs	organic light-emitting diodes
OPVs	organic photovoltaics
OTFTs	organic thin-film transistors
PCL	polycaprolactone
PCR	polymerase chain reaction
PDMS	polydimethylsiloxane

PEVA	poly(ethylene-co-vinyl acetate)
PH_3	phosphine
PHBV	poly(3-hydroxybutyrate-co-3-hydroxyvalerate)
PLA	poly (lactic acid)
PLGA	poly (lactic-co-glycolic acid)
PTCDA	perylene tetracarboxylic dianhydride
PU	polyurethane
QDs	quantum dots
RHEED	reflection high-energy electron diffraction
RNA	ribonucleic acid
rRNA	ribosomal RNA
SAM	self-assembled monolayer
SFM	scanning force microscopy
SHG	second-harmonic generation
siRNA	small-interfering RNA
SIS	styrene-isoprene-styrene
snoRNA	small nucleolar RNA
snRNA	small nuclear RNA
SPL	scanning probe lithography
SPM	scanning probe microscopes
STM	scanning tunneling microscope
SWCNTs	single-wall carbon nanotubes
SWNTs	single wall nanotubes
TEOS	tetraethyl orthosilicate
TMA	transcription-mediated amplification
TMD	transition metal dichalcogenides
TPD	temperature-programmed desorption
TPO	temperature-programmed oxidation
TPR	temperature-programmed reduction
tRNA	transfer RNA
TRPL	time-resolved photoluminescence
TUM	Technical University of Munich
UFP	ultrafine particles
UV	ultraviolet

VNPs	viral nanoparticles
XUV	extremely ultraviolet

PREFACE

Nanotechnology has accomplished a lot in just a few years. It is evident that nanotechnology will change dentistry, medical care, and human life more significantly than numerous technologies of the past. Likewise with all advancements, nanotechnology conveys a critical potential for misuse on a scale and extent never seen. However, they likewise can possibly achieve critical benefits, like improved wellbeing, better utilization of natural resources, and reduced environmental contamination. Nanotechnology has been utilized for dental applications in a few areas, including the field of prosthodontics with the advancement of nanobiomaterials as a helpful tool. Until now, there has been a dramatic expansion in examinations using nanotechnology for other dental applications. It is not too soon to consider, evaluate, and endeavor to shape possible impacts of nanodentistry. Nanodentistry will prompt productive and profoundly viable customized dental medicines. Nanotechnology is by all accounts where the world is going assuming innovation continues to progress, and competition basically ensures that technology will proceed. It will open a scope of opportunities or prospects for both the dental specialist and patient.

Over the past decade, the utilization of nanoparticles has become common in the development of numerous dental materials, since they offer a remarkable blend of properties. By the biggest application has been in dental composites, albeit a few exceptional glue structures containing nanoparticles have likewise been marketed. Each property has a basic length scale, and by utilizing building blocks less than the basic length scale, for example, nanoparticles—one can exploit the science of nanoparticles. An illustration of this is in light dissipation. Since nanoparticles have aspects well beneath the frequency of noticeable light (400–800 nm), they cannot dissipate that specific light bringing about incapacity to distinguish the particles by unaided eye. This has huge ramifications for controlling the optical properties of materials containing these particles. One more significant limitation to consider while utilizing nanoparticles is that due to their tiny size, they have a high surface region to volume proportion. Consequently, the exact control of the particle synthesis of the outer layer of nanoparticles becomes an essential part of quality and reproducibility of the nanoparticles.

This component is of significance since a critical component in nanotechnology is the capacity to intentionally control the group of the nanoparticles to offer the beneficial properties of the nanomaterial and a definitive exhibition of the materials into which they are consolidated.

Unmistakably, the different types of nanotechnology can possibly have a huge impact on society. Overall, it could be accepted that the use of nanotechnology will be gainful to people and businesses. Most of these applications include new materials which give profoundly various properties through working at the nanoscale, where new particularities are related with the exceptionally enormous surface area to volume proportions experienced at these aspects and with quantum impacts that are not seen with bigger sizes. The modern areas most promptly accepting nanotechnology are the data and communications area, including electronic and optoelectronic fields, food technology, energy technology and the clinical products, including a wide range of aspects of drugs and medication structures, diagnostics, and clinical technology, where the terms nanomedicine and bionanotechnology are now commonplace. Nanotechnology items may likewise offer novel opportunities for the decrease of environmental contamination.

A

Arc Method

An arc is formed by any two points on a demand curve, and the coefficient of price elasticity of demand of an arc is known as arc elasticity of demand. The arc elasticity is the elasticity of one variable with respect to another between two given points. It is used mostly in theories of mathematics and economics. It is the ratio of one variable's percentage change between two points to the other variable's percentage change (Figure 1) (Xia, 2008).

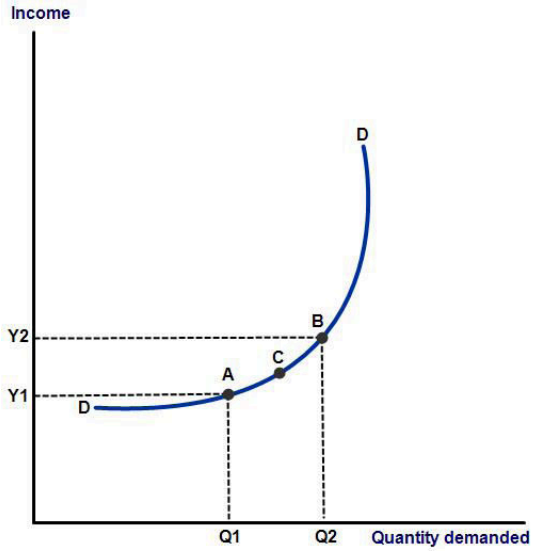


Figure 1. Arc elasticity.

Source: https://en.wikipedia.org/wiki/Arc_elasticity.

This method is used to determine the price elasticity of demand over a given price and quantity range. As a result, when the price or quantity requested of a commodity change significantly, this method is used to calculate price elasticity of demand.

In the figure, we can see that AB is an arc on the demand curve DD, and point C is the mid-point on AB. If we followed point method to measure PED at points A and B in the curve DD, we get different coefficients as a result of using different bases (Weiss et al., 2020). To avoid this discrepancy, elasticity is measured by taking mean values of price and quantity demanded in arc method.

Assembler Atom

Researchers at the CNRS's Institut d'Optique Graduate School and the Université Paris-Saclay in France have devised a new method for rearrangement of cold atoms in fully ordered arrays. Their method could be used to simulate quantum systems by trapping neutral atoms in 2D arrays of optical traps.

Optical traps, sometimes known as tweezers, trap atoms, molecules, or small transparent objects near the focus of a laser beam. Particles can be picked up and moved using only light in this technique (West and Halas, 2000).

They have played critical roles in the manipulation of viruses and proteins for medical research, as well as in the assembly of microscopic nanomachines. Holding cold atoms in arrays of optical traps has also proven tremendously beneficial to physicists since the arrays can replicate solid-state quantum physics. Creating such atom arrays, however, remains a difficulty.

Atomic Force Microscope (AFM)

The atomic force microscope (AFM) is widely used in materials research and has various applications in biological sciences, but its usage in vision science has been limited. The AFM can image the topography of soft biological materials in their natural settings. It can also be used to investigate the mechanical properties of cells and extracellular matrix (ECM), such as intrinsic elastic modulus and receptor-ligand interactions (Thompson, 2011). The operation of the AFM is discussed in this review, along with a discussion of how it has been applied in vision science thus far. It is hoped that this evaluation would encourage vision experts to consider including AFM as a research tool.

Atomic force microscopy is widely regarded as the most versatile and powerful microscopy technique for examining samples at the nanoscale. It is versatile because an AFM can not only image three-dimensional topography, but it also provides scientists and engineers with numerous forms of surface data. It is effective because an AFM can generate images at atomic resolution with angstrom scale resolution height information while requiring minimal sample preparation (Sozer and Kokini, 2009).

AFM is useful for measuring local electrical, mechanical, and other material properties, while it is most commonly used to visualize small-scale structure. It also works with a variety of materials, including those that are electrically conducting and insulating, transparent, and opaque, soft, and stiff, and so on.

As a result, AFM has become a "go-to" technique in a wide range of R&D applications, including molecular and cell biology, bottom-up assembly, and 2D materials, as well as industrial work in microelectronics, plastics, and rubbers, and energy storage and generation devices. The following application fields demonstrate AFM's power and versatility.

Atomic force microscopy (AFM) or scanning force microscopy (SFM) is a form of scanning probe microscopy (SPM) with resolution on the order of fractions of a nanometer (NM), which is more than 1,000 times greater than the optical diffraction limit. AFM is a form of scanning probe microscopy (SPM) with resolution on the scale of fractions of a NM, which is more than 1,000 times greater than the optical diffraction limit. The data is acquired by using a mechanical probe to "feel" or "touch" the surface. Precision scanning is enabled by piezoelectric components, which permit tiny but exact and precise movements on (electronic) command. Despite the name, the AFM does not use the nuclear force.

The AFM is capable of three major tasks: force measurement, topographic imaging, and manipulation. AFMs can be used to measure the forces between the probe and the sample as a function of their mutual separation in force measurement. For imaging, the probe's reaction to the pressures imposed by the sample can be used to provide a high-resolution image of the three-dimensional shape (topography) of a sample surface.

The forces between the tip and the sample can also be used to change the properties of the sample in a controlled manner during manipulation. Atomic manipulation, scanning probe lithography (SPL), and local cell stimulation are examples of this.

Atomic Layer Deposition (ALD)

ALD (atomic layer deposition) is a vapor phase process for depositing thin films onto a substrate. ALD involves exposing the surface of a substrate to alternating precursors that do not overlap but are introduced sequentially.

The precursor molecule reacts with the surface in a self-limiting manner in each alternate pulse, ensuring that the reaction terminates after all of the reactive sites on the substrate have been consumed. The nature of the precursor-surface contact determines the full ALD cycle. Depending on the requirements, the ALD cycle can be repeated numerous times to increase the layers of the thin film (Figure 2) (Arora et al., 2014).

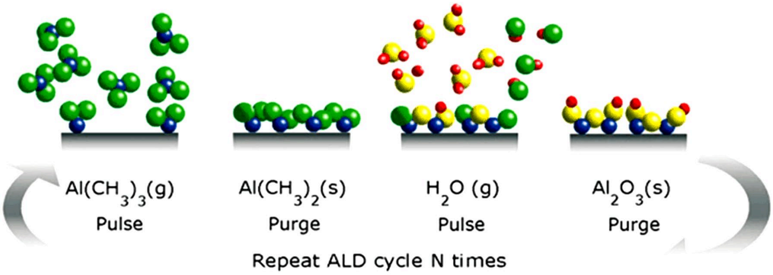


Figure 2. Atomic layer deposition (ALD).

Source: https://forgenano.com/atomic-layer-deposition/.

ALD is frequently performed at lower temperatures, which is advantageous when working with delicate substrates, and some thermally unstable precursors can still be used with ALD as long as their decomposition rate is moderate.

ALD may deposit a wide variety of materials, including oxides, metals, sulfides, and fluorides, and these coatings can have a variety of properties depending on the application (Smith et al., 2013).

The ALD technique is widely utilized because it produces ultra-thin nano-layers with high precision on a wide range of substrates, including micron to sub-micron particles. ALD nano-layers are conformal and pinhole-free by definition.

Automated Engineering

Automation engineering is an engineering subject that focuses on automating particular components of a system to improve the efficiency of various manufacturing and computer operations. Automation engineers develop and update existing technology to make it less reliant on human contact, and they keep track of how well the modifications work. An automation engineer may create totally new technology to automate a system on occasion. Traditional engineers who work with physical equipment or software engineers who work with programming languages are both examples of automation engineers.

Automation engineers are professionals who know how to design, build, develop, and manage machines and systems such as factory automation, process automation, and warehouse automation.

The integration of common engineering domains is referred to as automation engineering. Automated control of various control systems for operating various systems or machines in order to decrease human effort and time while increasing accuracy. Automation engineers create and maintain electromechanical devices and systems, such as high-speed robotics and programmable logic controllers (Seil and Webster, 2012).

Automation engineers may design, develop, simulate, and test automated machinery and processes. They are typically employed in industries such as the energy sector in plants, automobile manufacturing facilities, and food processing plants and robots.

Automated Manufacturing

Automated manufacturing is a way of producing goods that relies on the use of computerized control systems to operate equipment in a manufacturing plant. Because the system can manage both mechanical work and production task scheduling, no human operators are required on the assembly line or on the manufacturing floor. Fully automated manufacturing systems (AMS) were developed in the latter part of the 20th century, and they are now employed in facilities of various sizes all over the world.

Manufacturing used to be done totally by hand. This necessitated a significant amount of effort, raising the end product's cost and exposing employees to significant risk. Mechanized production was introduced during the Industrial Revolution. Instead of doing the work themselves, workers in automated manufacturing run machinery that accomplishes the work for them. This resulted in lower costs, greater consistency, and advancements in worker safety. The next phase in the process of refining and upgrading production methods was automated manufacturing (Sawhney et al., 2008).

An AMS is a networked system of material processing stations that can autonomously process a wide range of part types at the same time under computer control. The system is linked not just by a material transport system, but also by a communication network that allows all parts of manufacturing to be integrated. A system of this type is adaptable in terms of part routing, part processing, part handling, and tool changing. Furthermore, an AMS has the following characteristics: a high level of automation, a high level of integration, and a high level of adaptability.

Aerosol

An aerosol is a tiny solid particle or liquid droplet suspension in air or another gas. Aerosols can be both natural and manmade. Natural aerosols include fog or mist, dust, forest exudates, and geyser steam. Particulate air pollution and smoke are examples of anthropogenic aerosols. The liquid or solid particles typically have diameters less than 1 μm; larger particles with a high settling speed turn the mixture into a suspension, but the distinction is not evident (Sahoo and Labhasetwar, 2003). In general, an aerosol spray that distributes a consumer product from a can or similar container is referred to as an aerosol. Aerosols' other technological applications include pesticide dispersal, medicinal treatment of respiratory disorders, and combustion technology. Diseases can also spread through microscopic droplets in the breath, known as aerosols (or sometimes bioaerosols).

Aggregation

An aggregation is a collection or grouping of objects. Your baseball card collection could be made up of a variety of various types of cards.

Aggregation is derived from the Latin ad, which means "to," and gregare, which means "herd." As a result, the term was originally used to signify "herd" or "flock." It now simply refers to anything gathered in a collection or assemblage. If you work in a lab, for example, you may be tasked with sample collection prior to experiments (Safari and Zarnegar, 2014).

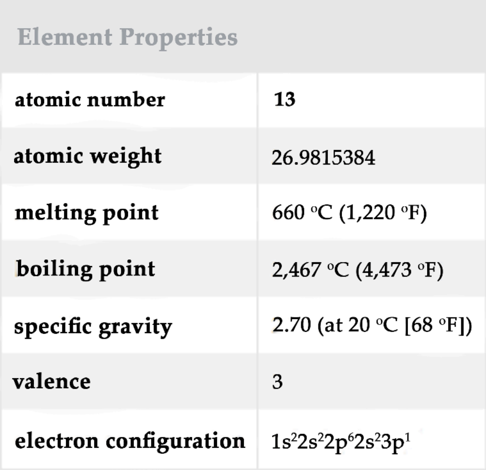
Alkali Metals

The chemical elements lithium (Li), sodium (Na), potassium (K), rubidium (Rb), Caesium (Cs), and francium make up the alkali metals (Fr). Together with hydrogen, they form group 1, which is located in the periodic table's s-block. All alkali metals contain an s-orbital outermost electron; this shared electron configuration leads in very similar characteristic features. Indeed, the alkali metals are the best example of periodic table group trends in characteristics, with elements exhibiting well-characterized homologous behavior. This element family is also known as the lithium family after its leading element, lithium.

Because of their strong reactivity, they must be stored under oil to avoid reaction with air, and they are only found naturally in salts, never as free elements. Cesium, the fifth alkali metal, is the metal with the highest reactivity. All alkali metals react with water, with heavier metals reacting more forcefully than lighter metals.

Aluminum nanoparticles

Aluminum (Al) is a light silver-white metal compound in periodic group 13 (IIIa or boron group). Aluminum is a popular non-ferrous metal and the most abundant metallic compound in the earth's crust. Nanoscale aluminum particles are normally 10-30 nanometers (nm) and have a specific surface area (SSA) in the 30-70 m2/g range, also available with an average particle size in the 70-100 nm range SSA and about 5 - 10 m2/g. The most common method for synthesizing aluminum nanoparticles is to evaporate aluminum from the molten state into an inert gas-filled chamber, where the metallic gas condenses. Aluminum nanoparticles (Al NPs) are used in a variety of applications such as material surface coating, drug delivery, and components of solid rocket fuels in army explosives and weaponry.



Element Properties	
atomic number	**13**
atomic weight	26.9815384
melting point	660 °C (1,220 °F)
boiling point	2,467 °C (4,473 °F)
specific gravity	2.70 (at 20 °C [68 °F])
valence	3
electron configuration	$1s^2 2s^2 2p^6 2s^2 3p^1$

Figure 3. Element properties.

Source: https://www.britannica.com/science/aluminum.

B

Biomimetics

Biomimetics is an interdisciplinary field in which engineering, chemistry, and biology principles are applied to the creation of materials, synthetic systems, or machines that replicate biological processes. Any natural or synthetic material that interacts with any aspect of a biological system is referred to as a biomaterial. Biomimetic designs have the potential to be applied in regenerative medicine, tissue engineering, and medication delivery.

The study of nature, its models, systems, processes, and elements to replicate or take inspiration from in order to address human issues is known as biomimicry or biomimetics. Biomimicry and biomimetics are derived from the Greek terms bios, which means life, and mimesis, which means to copy. Bionics is a term that is similar to bionics (Porter et al., 2008). Nature has refined the living beings, processes, and materials on planet Earth over the previous 3.6 billion years through trial and error. At both the macro and nanoscale levels, the rising science of biomimetics has given rise to novel technologies derived from biologically inspired engineering. Biomimetics is not a brand-new concept.

Throughout history, humans have looked to nature for solutions to both complicated and simple problems. Through the evolutionary mechanics of selected advantages, nature has solved many of today's engineering difficulties, such as hydrophobicity, wind resistance, self-assembly, and solar energy harvesting.

Biomimetics, also known as biomimicry, is the imitation of natural models, systems, and elements in order to solve complicated human issues. The names "biomimetics" and "biomimicry" come from Ancient Greek: o (bios), life, and (mmsis), imitation, from (mmeisthai), to imitate, from (mimos), actor. Bionics is a closely related field.

Natural selection has resulted in the evolution of well-adapted structures and materials in living beings across geological time. Biomimetics has given rise to new technologies at the macro and nanoscales that are inspired by biological solutions.

Throughout history, humans have looked to nature for solutions to challenges. Nature has solved engineering difficulties such as self-healing, environmental tolerance and resistance, hydrophobicity, self-assembly, and solar energy harvesting (Patil et al., 2008).

Buckyball

Buckminsterfullerene is the chemical that makes up a buckyball. Buckyballs, which are made up of 60 carbon atoms organized into the shape of a hollow ball, have no practical value as of yet, however they do make up nanotubes, which have some applications.

Buckyballs sparked a lot of interest in scientific circles and earned Curl, Kroto, and Smalley the Nobel Prize in 1996, all before any practical application could be imagined. Nonetheless, scientists sought ways to mass-produce them, if only to investigate their unique features. Buckyballs, they discovered, could bounce, revert to their original shape when squeezed, and spin at incredible speeds.

Buckminsterfullerene, with the formula C60, is a kind of fullerene. It is constructed of 20 hexagons and 12 pentagons and has a cage-like fused-ring structure (truncated icosahedron) that resembles a soccer ball (Pathakoti et al., 2018). Each carbon atom is connected by three bonds. It is a dark solid that dissolves in hydrocarbon solvents to form a violet solution. Although the chemical has been extensively researched, few real-world applications have been discovered.

The buckyball, which is now over a decade old, has sparked a lot of interest but is still in its infancy as a commercial product. The slow progress in finding practical applications has not, however, discouraged the hundreds or thousands of companies and individual scientists investigating ways to make or use these interesting new molecules.

Buckyballs can be used to trap free radicals produced during an allergic reaction and reduce inflammation. Buckyballs' antioxidant characteristics may help to prevent motor function degeneration caused by multiple sclerosis.

Buckyballs, nanotubes, and polymers are used to create low-cost solar cells that may be manufactured simply by painting a surface. Buckyballs could be utilized to store hydrogen and could even be used as a fuel tank for fuel cell vehicles.

Buckyballs may be able to inhibit bacteria development in water system pipes and membranes. Researchers are attempting to modify buckyballs to fit the section of the HIV molecule that binds to proteins, possibly inhibiting the spread of the virus. Making bulletproof vests with inorganic (tungsten disulfide) buckyballs.

Bulk Technology

Technology that is based upon the manipulation of atoms and molecules in bulk – as distinct from that involving individual atoms or molecules in nanotechnology, etc.

Biopolymer

Biopolymers are natural polymers created by living organisms' cells. Monomeric units are covalently bound to generate bigger molecules in biopolymers. Polynucleotides, polypeptides, and polysaccharides are the three primary groups of biopolymers, which are categorized based on the monomers employed and the structure of the biopolymer generated. Polynucleotides are lengthy polymers made up of 13 or more nucleotide monomers, such as RNA and DNA. Polypeptides and proteins are polymers of amino acids, with collagen, actin, and fibrin being notable examples. Starch, cellulose, and alginate are examples of polysaccharides, which are linear or branched polymeric carbohydrates (Nikalje, 2015).

Natural rubbers (polymers of isoprene), suberin, and lignin (complex polyphenolic polymers), cutin, and cutan (complex polymers of long-chain fatty acids), and melanin are all examples of biopolymers. Biopolymers are used in a variety of industries, including food, manufacturing, packaging, and biomedical engineering. The structural differences between biopolymers and manmade polymers are significant. All polymers are composed of repeated components known as monomers. Biopolymers frequently have a well-defined structure, albeit this is not a distinguishing feature (for example, lignocellulose): In the case of proteins, the fundamental structure is the specific chemical composition and sequence in which these units are assembled. Many biopolymers spontaneously fold into characteristic compact shapes (see also "protein folding" as well as secondary and tertiary structure), which influence their biological functions and rely on their primary structures in a sophisticated way.

Biosensor

A biosensor is an analytical instrument that combines a biological component with a physicochemical detector to detect a chemical molecule. The sensitive biological element, which may include tissue, bacteria, organelles, cell receptors, enzymes, antibodies, nucleic acids, and so on, is a biologically generated substance or biomimetic component that interacts with, binds to, or recognizes the analyte under investigation. Biological engineering can also be used to develop biologically sensitive elements. The transducer or detector element that converts one signal into another operates in a physicochemical manner: optical, piezoelectric, electrochemical, electrochemiluminescence, and so on, resulting from the interaction of the analyte with the biological element, to easily measure and quantify (Abolmaali et al., 2013).

The biosensor reader device communicates with the related electronics or signal processors, which are primarily in charge of displaying the results in an understandable manner. This is sometimes the most expensive component of the sensor device, but it is possible to create a user-friendly display that contains the transducer and sensitive element (holographic sensor). The readers are often custom-designed and built to accommodate the various working principles of biosensors.

Biosensors are currently widely used in biomedical diagnostics, as well as point-of-care monitoring of treatment and illness progression, environmental monitoring, food control, drug discovery, forensics, and biomedical research. Biosensors can be developed using a wide range of methodologies. Their interaction with high-affinity biomolecules enables sensitive and selective detection of a variety of analytes.

The glucose monitor, which diabetics use on a regular basis to check their blood sugar level, is one well-known example of a therapeutically utilized biosensor. These devices detect blood glucose levels in undiluted blood samples, allowing for simple self-testing and monitoring, which has transformed diabetes management (Baruah and Dutta, 2009).

During quality control operations in the food sector, biosensors are used to measure carbohydrates, alcohols, and acids, for example. The gadgets can also be used to monitor fermentation in beer, yogurt, and soft drinks production. Their usage in identifying infections in fresh meat, poultry, or fish is another key application (Figure 4).

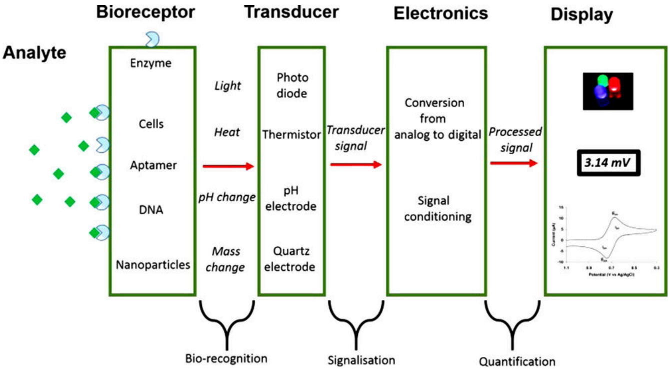


Figure 4. A biosensor.

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4986445/.

Biosynthesis

In living organisms, biosynthesis is a multi-step, enzyme-catalyzed process by which substrates are transformed into more complex products. Simple chemicals are changed, transformed into other compounds, or linked together to produce macromolecules during biosynthesis. This procedure frequently involves metabolic pathways. Some of these biosynthetic processes involve enzymes found in a single cellular organelle, whereas others involve enzymes found in numerous cellular organelles. These metabolic pathways include the synthesis of lipid membrane components and nucleotides, to name a few. Anabolism is commonly associated with biosynthesis (Bohr, 2002).

Biosynthesis in living organisms is a process in which substrates are converted to more complex products. The products which are produced as a result of biosynthesis are necessary for cellular and metabolic processes deemed essential for survival.

Precursor molecules, chemical energy (e.g., ATP), and catalytic enzymes (which may require coenzymes) are all required for biosynthesis (e.g., NADH, NADPH). These components combine to form monomers, which serve as the building blocks for macromolecules. Proteins, which are made up of amino acid monomers linked together by peptide bonds, and DNA molecules, which are made up of nucleotides linked together by phosphodiester bonds, are two examples of major biological macromolecules.

Block Copolymers

A copolymer is a polymer produced from more than one monomer species in polymer science. Copolymerization is the polymerization of monomers into copolymers. Bipolymers are copolymers formed by the copolymerization of two monomer types. Terpolymers and quaterpolymers are those formed from three and four monomers, respectively (Mnyusiwalla et al., 2003).

Commercial copolymers include acrylonitrile butadiene styrene (ABS), styrene/butadiene co-polymer (SBR), nitrile rubber, styrene-acrylonitrile, styrene-isoprene-styrene (SIS), and ethylene-vinyl acetate.

A block copolymer is a polymer composed of molecules with a linear arrangement of blocks, where a block is defined as a piece of a polymer molecule in which the monomeric units have at least one constitutional or configurational trait that the surrounding portions do not have. The defining property of a block copolymer is constitutional, which means that each of the blocks is made up of units generated from a certain species of monomer. This concept eliminates branched structures made up of blocks, such as star or radical block copolymers.

Because a copolymer is made up of at least two different types of constituent units (also known as structural units), copolymers can be classed according to how these units are organized along the chain. Linear copolymers, which include alternating copolymers, statistical copolymers, and block copolymers, are made up of a single main chain. Branched copolymers are made up of a single main chain and one or more polymeric side chains, and they can be grafted, star-shaped, or have different topologies.

Current applications of block copolymers include thermoplastic elastomers and compatibilization of polymer blends. The potential uses of block copolymers in immerging technologies like nanotechnology, nanolithography (NL), photonics, and controlled drug delivery are enormous.

C

Carbon Nanotubes (CNTs)

Carbon nanotubes (CNTs) are carbon tubes with diameters measured in nanometers (NMs). CNTs are commonly used to refer to single-wall carbon nanotubes (SWCNTs) having dimensions in the NM range. SWCNTs are a type of carbon allotrope that exists between fullerene cages and flat graphene.

Although they are not formed in this manner, SWCNTs can be idealized as cutouts from a two-dimensional hexagonal lattice of carbon atoms rolled up along one of the hexagonal lattice's Bravais lattice vectors to form a hollow cylinder (Figure 5).

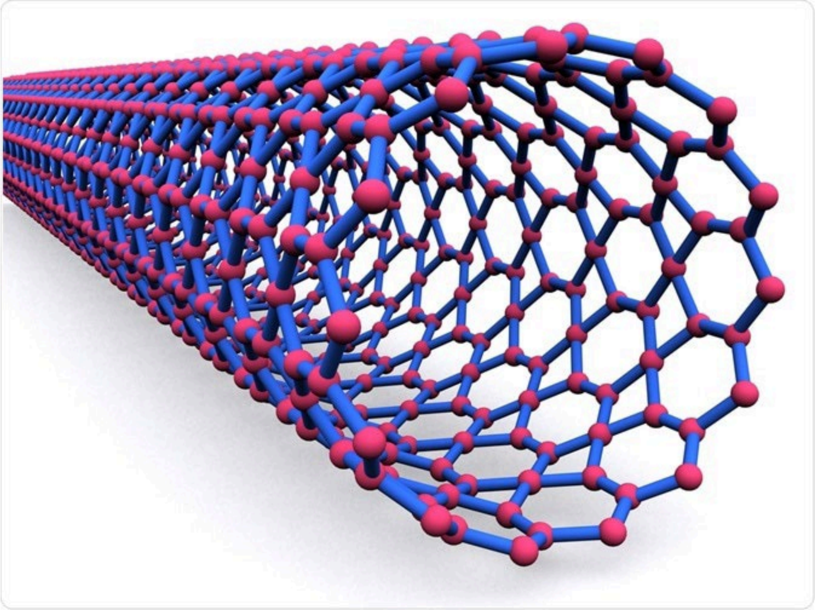


Figure 5. Carbon nanotube (CNT).

Source: https://en.wikipedia.org/wiki/Carbon_nanotube.

Periodic boundary conditions are applied along the length of this roll-up vector in this construction, resulting in a helical lattice of flawlessly connected carbon atoms on the cylinder surface.

CNTs are also commonly used to describe multi-wall carbon nanotubes (MWCNTs), which are made up of nested SWCNTs that are weakly bonded together by van der Waals interactions in a tree ring-like structure. These tubes are very akin, if not identical, to Oberlin, Endo, and Koyama's long straight and parallel carbon layers cylindrically stacked around a hollow tube. The term "multi-wall carbon nanotubes" can also apply to double- and triple-wall carbon nanotubes (Morrow et al., 2007).

Colloid

A colloid is a mixture in which one material is suspended throughout another, consisting of microscopically dispersed insoluble particles. Nevertheless, some definitions require the particles to be dispersed in a liquid, while others broaden the concept to include aerosols and gels. The term colloidal suspension definitely refers to the total combination (although a narrower sense of the word suspension is distinguished from colloids by larger particle size).

Colloid, any substance consisting of particles substantially larger than atoms or ordinary molecules but too small to be visible to the unaided eye; more broadly, any substance, including thin films and fibers, having at least one dimension in this general size range.

A colloid has two phases: dispersed (the suspended particles) and continuous (the medium of suspension). The dispersed phase particles range in size from 1 nanometer to 1 micrometer.

All colloidal systems can be either generated or eliminated by nature as well as by industrial and technological processes. The colloids prepared in living organisms by biological processes are vital to the existence of the organism. Those produced with inorganic compounds in Earth and its waters and atmosphere are also of crucial importance to the well-being of life-forms (Mousavi and Rezaei, 2011).

Colloids are thickening agents used in lubricants, lotions, toothpaste, coatings, and other commercial items. Colloids are important in the production of paints and inks. Gel ink is used in ball-point pens (liquid-solid colloid). Sulfates of aluminum (alum) and iron, which coagulate the suspended contaminants in natural water, are used to eliminate them.

The majority of the medications are colloidal in nature. For muscular vitality, colloidal gold and calcium are injected into the human body. As an eye lotion, argyrol (silver sol) is utilized. Other colloids used in medicine include albumin, hetastarch, and Dextran.

Converging Technologies

Technological convergence, also known as digital convergence, is the tendency for previously independent technologies to become increasingly closely integrated, if not united, as they develop and improve. Watches, telephones, televisions, computers, and social media platforms, for example, began as separate and mostly unrelated technologies, but have converged in many ways into interconnected parts of the telecommunications and media industry, sharing common elements of digital electronics and software.

The five factors of technological convergence are as follows:

- Technology, it is normal for technologies that are perceived to be quite different to develop comparable features that blur differences over time. A television and a cell phone were two completely different things in 1995. They may have similar functionality in recent years, such as the capacity to connect to Wi-Fi, play rich internet-based media, and run apps. People can use the same software to play a game or connect with family on their television or phone (Mitter and Hussey, 2019).

- Media and content, television, and internet services were long considered different entities, but they have begun to converge. Music, movies, video games, and instructional content are all likely to converge to the point where they are no longer different media. Future music, for example, may always have an interactive music video that mimics a game.
- In the late 1990s, there was a significant divide between corporate and consumer software and services. This line has become increasingly hazy over time. Technology tends to shift away from a large number of highly specific tools and toward a limited set of versatile instruments with broad uses.
- Music, movies, video games, and informational content are all likely to merge to the point where they are no longer different media. For example, future music may always have an interactive music video that mimics a game (Mei et al., 2011).
- In the late 1990s, there was a significant distinction between corporate and consumer software and services. With the passage of time, this distinction has become increasingly hazy. Technology tends to shift away from a big number of highly particular instruments and toward a small collection of flexible tools with broad applicability.

Cell Pharmacology

The study of medication impacts on diverse cell processes is referred to as cellular pharmacology. Flow cytometry enhances cellular pharmacology by providing the following analytical opportunities. To begin, determining hazardous doses can be approached by the examination of cell viability. However, due to the availability of several fluorescent DNA probes, the majority of studies are devoted to the investigation of goods that effect on cell division, particularly antineoplastic medications. The impact of medications on respiration can be studied by examining mitochondrial activity.

Antisera or monoclonal antibodies to cell-specific proteins such as collagen and keratin, on the other hand, have been used in studies of pharmacological activities on cell differentiation processes. Flow cytometry appears to be becoming increasingly significant in the advancement of cellular toxicology and pharmacology (Marcato and Durán, 2008).

Pharmacology is being transformed from a conventional discipline of drug action description to an examination of biological molecular roles for effective drug creation. Our group is investigating a novel pharmacological approach that focuses on the roles of prostaglandin receptors and Rho small G proteins. Such a strategy necessitates the integration of multi-level understanding, beginning at the molecular and cellular levels and progressing to the whole-system level. Regardless of educational background, we encourage young energetic people interested in physiology and medicine to join our organization.

Cell Surgery

Cell therapy is a type of treatment that uses cells. A technique that involves replacing sick or malfunctioning cells with healthy, functional ones.

Cell therapy includes whole blood transfusions, packed red cell transfusions, platelet transfusions, bone marrow transplants, and organ transplants. Some types of cancer, neurological illnesses such as Parkinson's disease and amyotrophic lateral sclerosis (Lou Gehrig's disease), spinal cord injuries, and diabetes may benefit from cell therapy.

Blood and bone marrow cells, mature and immature solid tissue cells, adult stem cells, and, most contentiously, embryonic stem cells can all be used in cell therapy. With the advent of cellular surgery, it is now possible to create procedures that are more effective and specifically tailored to provide patients with the desired results. Small incisions are created to acquire regenerative cells from the patient's own body, which are responsible for healing, nourishing, and directing the functioning of the tissues in which they live. Important therapeutic effects are obtained in a minimally invasive manner when concentrated and implanted (Manjunatha et al., 2016). The implantation of these cells beneath the skin improves the recovery of the viscoelastic characteristics of the skin injured by burns or scars, as well as the treatment of persistent ulcers.

Cell

In biology, a cell is a basic membrane-bound unit that contains the fundamental molecules of life and is made up of which all living organisms are made. A single cell, such as a bacterium or yeast, is frequently a complete organism in and of itself. As cells age, they develop specialized functions. These cells collaborate with other specialized cells to form the foundation of huge multicellular organisms like humans and other animals. Cells are far larger than atoms, but they are still quite small. Mycoplasmas, a genus of tiny bacteria, are the tiniest known cells; some of these single-celled organisms are spheres as small as 0.2 m in diameter (1 µm = about 0.000039 inch), with a total mass of 10−14 gram—equal to that of 8,000,000,000 hydrogen atoms.

Human cells have a mass 400,000 times greater than a single mycoplasma bacterium, however even human cells are only approximately 20 m wide. A sheet of around 10,000 human cells would be needed to cover the head of a pin, while each human organism is made up of more than 30,000,000,000,000 cells.

A cell is surrounded by a plasma membrane, which serves as a selective barrier that permits nutrients to enter while allowing waste products to exit. The cell's interior is divided into several specialized compartments, or organelles, each enclosed by its own membrane. The nucleus, a key organelle, provides the genetic information required for cell growth and reproduction (Lü et al., 2009). Each cell has a single nucleus, but other organelles are present in many copies in the cellular contents, or cytoplasm. Organelles include mitochondria, which are in charge of the energy transactions required for cell viability, and lysosomes, which decompose waste within the cell and the endoplasmic reticulum and the Golgi apparatus, which play important roles in the internal organization of the cell by synthesizing selected molecules and then processing, sorting, and directing them to their proper locations.

Chemical Vapor Deposition (CVD)

Chemical vapor deposition (CVD) is a vacuum deposition technology used to create high-quality, high-performance solid materials. Thin films are frequently produced using this method in the semiconductor sector.

The wafer (substrate) is often exposed to one or more volatile precursors, which react and/or degrade on the substrate surface to generate the desired deposit. Volatile by-products are frequently created and eliminated by gas flow through the reaction chamber (Lieber, 2003).

CVD is frequently used in microfabrication techniques to deposit materials in a variety of morphologies, including monocrystalline, polycrystalline, amorphous, and epitaxial. Silicon (dioxide, carbide, nitride, oxynitride), carbon (fiber, nanofibers, nanotubes, diamond, and graphene), fluorocarbons, filaments, tungsten, titanium nitride, and different high-k dielectrics are among these materials.

CVD is frequently used to produce conformal coatings and modify substrate surfaces in ways that other surface modification techniques cannot. When it comes to producing incredibly thin layers of material, CVD is incredibly useful in the process of atomic layer deposition (ALD).

Such films have a wide range of applications. Some integrated circuits (ICs) and solar devices contain gallium arsenide. Photovoltaic gadgets make use of amorphous polysilicon. Wear resistance is conferred by some carbides and nitrides. CVD polymerization, possibly the most diverse of all applications, enables super-thin coatings with desirable properties such as lubricity, hydrophobicity, and weather resistance, to mention a few. Recently, CVD of metal-organic frameworks, a family of crystalline nanoporous materials, was demonstrated (Lakhal and Wood, 2011).

Recently scaled up as an integrated cleanroom process depositing large-area substrates, these films are expected to have used in gas sensing and low-k dielectrics. CVD processes are also advantageous for membrane coatings, such as those used in desalination or water treatment, because they can be uniform (conformal) and thin enough not to clog membrane pores.

CVD can be used in a variety of sectors, including:

- **Coatings:** These for wear resistance, corrosion resistance, high temperature protection, erosion protection, and combinations thereof.
- **Semiconductors and Associated Devices:** Integrated circuits, sensors, and optoelectronic devices are examples of semiconductors and related devices.
- **Dense Structural Parts:** CVD can be utilized to make components that would be difficult or expensive to make using traditional fabrication methods. CVD-produced dense pieces are typically thin-walled and placed onto a mandrel or former.
- **Optical Fibers:** These are used in telecommunications.
- **Composites:** Preforms can be infiltrated using CVD techniques to produce ceramic matrix composites such as carbon-carbon, carbon-silicon carbide, and silicon carbide-silicon carbide

composites. This process is sometimes called chemical vapor infiltration or CVI.

- **Powder Production:** Production of novel powders and fibers.
- **Catalysts:** Substance that increases chemical reaction.
- **Nanomachines:** Mechanical tool whose dimensions are calculated in nanometers.

Carbon

Carbon (from the Latin carbo, which means "coal") is a chemical element with the symbol C and the atomic number 6. It is nonmetallic and tetravalent, which means it can form covalent chemical connections with four electrons. It is in Periodic Group 14 of the periodic table. Carbon accounts for only approximately 0.025% of the Earth's crust. Natural isotopes include 12C and 13C, which are stable, and 14C, which is a radioactive with a half-life of around 5,730 years. Carbon is one of the few elements that have been known since antiquity.

Carbon is the 15th most plentiful element in the Earth's crust and, by mass, the fourth most abundant element in the universe, following hydrogen, helium, and oxygen (Klimeck et al., 2008).

Carbon's abundance, unique range of organic compounds, and rare ability to form polymers at typical Earth temperatures allow it to serve as a common ingredient of all known life. After oxygen, it is the second most prevalent element in the human body by mass (approximately 18.5%).

Carbon atoms can link in a variety of ways, resulting in distinct carbon allotropes. Graphite, diamond, amorphous carbon, and fullerenes are examples of well-known allotropes.

The most abundant inorganic carbon sources are limestones, dolomites, and carbon dioxide, although significant amounts can also be found in organic deposits such as coal, peat, oil, and methane clathrates. Carbon creates the most compounds of any element, with about 10 million compounds identified to date, but that figure is still a fraction of the theoretically potential compounds under standard conditions. Be a result, carbon is frequently referred to as the "king of the elements."

Carbon allotropes include graphite, which is one of the softest known substances, and diamond, which is the hardest naturally existing solid. It easily binds with other tiny atoms, including other carbon atoms, and can create numerous stable covalent connections with appropriate multivalent atoms. Carbon is known to generate nearly 10 million compounds, accounting for the vast bulk of all chemical molecules.

The following are some of the most important applications:

- It accounts for 18% of the human body's mass. It is what sugar, glucose, proteins, and other substances are comprised of. Carbohydrates are an important source of energy found in the foods we eat. Carbohydrates are nothing more than carbon atoms.
- The diamond form of carbon is employed in jewelry. However, diamonds are also employed in industry. Because it is the hardest substance known to man, it has a wide range of applications in manufacturing (Kung and Kung, 2004).
- Inks and paints are made from amorphous carbon. It is also used in the manufacture of batteries.
- The lead in your pencils is made of graphite. It is also utilized in the steel-making process.
- Carbon dating is one of the most common applications. Carbon can be used to determine the age of objects. Carbon-14, a rare type of carbon, is used by scientists to determine the age of fossils, bones, and other objects. The emission of carbon-14 is recorded in order to calculate the life of the organic component in question. Scientists use this method to determine the age and period of dinosaur bones and fossils.
- As you can see from the statistics above, carbon is a fascinating element with numerous applications. This is why a thorough understanding of it is required in Chemistry.

Cell Adhesion

Cell adhesion is the process by which cells interact with and connect to neighboring cells via specialized cell surface chemicals. This procedure can take place either directly between cell surfaces, such as cell junctions, or indirectly, where cells adhere to the surrounding extracellular matrix (ECM), a gel-like material holding chemicals released by cells into spaces between them. Cell adhesion is caused by interactions between cell-adhesion molecules (CAMs), which are transmembrane proteins found on the cell surface. Cell adhesion connects cells in various ways and can be involved in signal transduction, allowing cells to detect and respond to changes in their environment (Kaur et al., 2014).

Cell migration and tissue formation are two more biological processes governed by cell adhesion in multicellular organisms. Cell adhesion changes can disrupt critical biological processes and contribute to a number of illnesses, including cancer and arthritis. Infectious organisms, such as bacteria or viruses, require cell attachment to induce disease.

Cell adhesion is necessary for cell communication and control, as well as for tissue formation and maintenance. Mechanical interactions between cells and their ECM can influence and regulate cell behavior and function. Because cell adhesion is such an important function, there has been a lot of interest in creating methods for measuring and researching cell adhesion features. Cell adhesion research may be divided into two categories: cell adhesion attachment and cell adhesion dissociation events. Cell adhesion has been extensively studied using both events for a variety of essential reasons in cellular biology, biomedical, and engineering domains.

Cell adhesion attachment and detachment events can be classified into two categories: cell population and single-cell approach. Various techniques to measure cell adhesion have been applied to many fields of study in order to gain a better understanding of cell signaling pathways, biomaterial studies for implantable sensors, artificial bone and tooth replacement, tissue-on-a-chip, and organ-on-a-chip development in tissue engineering, the effects of biochemical treatments and environmental stimuli on cell adhesion, the potential of drug treatments, cancer metastasis study, and the determination of cellular morphology (Kandel et al., 2013).

Plant cells are connected with plasmodesmata, which are channels that cross-plant cell walls and join the cytoplasms of neighboring plant cells. Through plasmodesmata, molecules that are either nutrients or growth signals are transferred passively or selectively between plant cells.

Protozoans produce a variety of adhesion molecules with varied specificities that attach to carbohydrates on their host cells’ surfaces. Pathogenic protozoans rely on cell-cell adhesion to connect to and infiltrate their host cells.

The malarial parasite (Plasmodium falciparum) uses one adhesion molecule called the circumsporozoite protein to adhere to liver cells and another adhesion molecule called the merozoite surface protein to bind red blood cells as an example of a dangerous protozoan.

Pathogenic fungi use adhesion molecules present on its cell wall to attach, either through protein-protein or protein-carbohydrate interactions, to host cells or fibronectins in the ECM (Huang et al., 2010).

Prokaryotes have adhesion molecules on their cell surface termed bacterial adhesins, apart from using its pili (fimbriae) and flagella for cell adhesion. Viruses also have adhesion molecules required for viral binding to host cells. For example, influenza virus has a hemagglutinin on its surface that is required for recognition of the sugar sialic acid on host cell surface molecules.

Cell Recognition

A cell's ability to recognize one type of nearby cell from another is known as cell-cell recognition. When complementary molecules on opposing cell surfaces collide, this event happens. A receptor on the surface of one cell interacts with a ligand on the surface of another neighboring cell, triggering a series of events that control cell behaviors ranging from simple adhesion to complicated cellular differentiation. Cell-cell recognition, like other biological functions, is affected by harmful mutations in the genes and proteins involved and is vulnerable to mistake. Animal development, microbiomes, and human medicine all benefit from the biochemical activities that occur as a result of cell-cell recognition (Gunasekaran et al., 2014).

When two molecules restricted to the plasma membranes of distinct cells connect to each other, a reaction for communication, collaboration, transport, defense, and/or development is triggered. Rather than eliciting a remote reaction, as released hormones can, this sort of binding necessitates the cells that contain the signaling molecules to be in close proximity to one another. Intrinsic recognition and extrinsic recognition are the two basic categories of these events. Intrinsic recognition occurs when cells from the same organism come together. Extrinsic recognition occurs when a cell from one creature recognizes a cell from another organism, such as when a mammalian cell recognizes a microorganism in the body.

Proteins, carbs, and lipids are the molecules that complete this binding, resulting in a variety of glycoproteins, lipoproteins, and glycolipoproteins. Glycan-glycan interactions, which have been found to be around 200–300 pN, may also play a role in cell-cell recognition, according to research. Complex carbohydrates, in particular, have been shown to play a critical role in cell-cell recognition, particularly when complementary carbs are present. Complex carbohydrates and their complementary carbohydrates are able to construct flexible interaction systems by ensuring a correct binding location by monitoring the surrounding areas or securing a previously created bond. These interactions, although observed to be weak, have been studied in a variety of test subjects including, but not limited to, mouse embryonal cells, corneal epithelial cells, and human embryonal carcinoma cells.

Sponge cells, the most primitive category in the animal kingdom, show one of the simplest forms of cell-cell attachment recognition. Sponges form when individual cells clump together to form larger clusters. Individual sponge cells use membrane-binding proteins and released ions to coordinate aggregation while avoiding fusion between distinct species or even individuals. When attempts to graft sponge cells from various species or individuals of the same species failed, but attempts utilizing cells from the same individual succeeded, this was revealed (Figure 6).

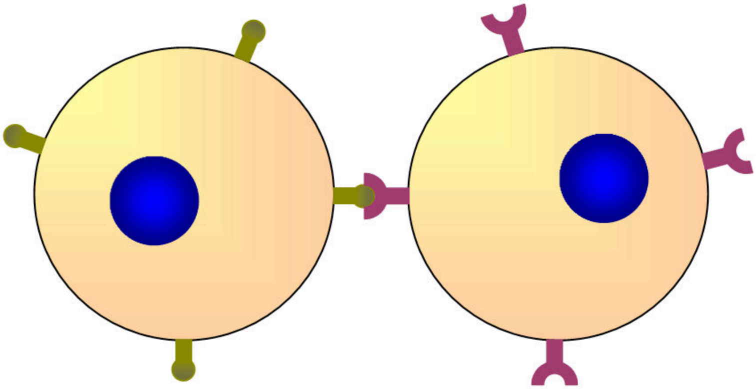


Figure 6. Two cells communicating via their respective surface molecules.

Source: https://en.wikipedia.org/wiki/Cell%E2%80%93cell_recognition#/media/File:Illustration_of_Cell-Cell_Recognition.png.

Cell-cell recognition is frequently engaged in getting particular types of cells to the location of an injury in a large multicellular organism. Selectin-expressing cells in animals are a good illustration of this. Selectin is a membrane-bound glycan-binding receptor protein present on the membranes of leukocytes, platelet cells, and endothelial cells. Endothelial cells produce selectin in response to damage, which binds to glycans on the surface of leukocyte cells (Gupta, 2011). On their way to the endothelial cells, platelet cells use their selectins to associate with leukocytes. Leukocytes then use their own selectins to recognize potential pathogens at the site of the injury. In this manner, the appropriate cells are brought to the site of an injury to deal with immediate repair or invading microorganisms.

Characterization

Nanoparticle characterization is a branch of nanometrics that involves characterizing or measuring the chemical and physical elements of nanoparticles. Techniques that can be employed to characterize nanoparticles include electron microscopy, especially scanning probe microscopy, X-ray diffraction, neutron diffraction, atomic force microscopy, X-ray scattering, X-ray fluorescence spectroscopy, sonication, and contact angle measurements. Characterization of the physical and chemical properties of nanoparticles is important to ensure the reproducibility of toxicology studies, it is also critical to study how the chemical and physical properties of nanoparticles determine their biological impacts.

In materials science, characterization refers to the broad and generic process of probing and measuring a material's structure and properties. It is a crucial step in the field of materials science, without which no scientific understanding of engineering materials would be possible. Some definitions confine the term's application to techniques that examine the microscopic structure and properties of materials, while others apply it to any materials analysis process, including macroscopic techniques like mechanical testing, thermal analysis, and density computation (Farokhzad and Langer, 2009). The scale of the structures observed in materials characterization ranges from angstroms, such as in the imaging of individual atoms and chemical bonds, up to centimeters, such as in the imaging of coarse-grain structures in metals.

Characterization procedures are used for a variety of purposes, including identifying product materials, detecting contaminants and degradants, and constructing a chemical profile of an unknown formulation. By removing some variables from the investigation, characterization might be a useful initial step before doing a more intensive impurity identification study.

Chemical Vapor Transport (CVT)

Chemical vapor transport (CVT), a technique pioneered by Schäfer, is a process in which a condensed phase, often a solid, is volatilized and deposited elsewhere in the form of crystals in the presence of a gaseous reactant (transport agent). Halogens and halogen compounds are common transport agents. A two-zone furnace (source T2 and sink T1), as well as the reactant and transport agent, are all contained in one ampoule. Growth temperature, transport direction, mass transport rate, transport agent selection, and reaction-free energy are some of the characteristics that must be optimized for a successful CVT.

Convection and diffusion are the two mechanisms that govern transportation. Though larger crystals can be generated by favoring convection and boosting transport rates, the crystals are inhomogeneous and prone to additional flaws. As a result, optimizing each chemical system is critical. The source and sink temperatures must be adjusted based on the free energy of the reaction between the species (Ehdaie, 2007). An exothermic reaction shows movement from the cold to the hot zone, while an endothermic reaction indicates the opposite. Also, no transfer occurs if the reaction between the species is highly exothermic or endothermic (Figure 7).

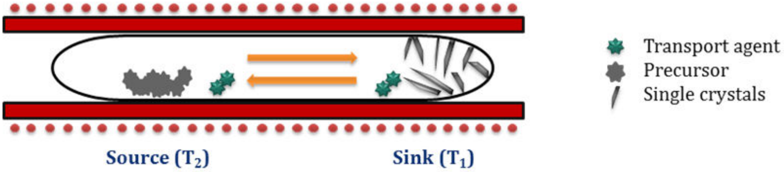


Figure 7. Schematic of the experimental set-up.

Source: https://www.cpfs.mpg.de/2651362/chemical-vapor-transport.

Single crystals of transition metal dichalcogenides (TMD) and pnictides have been obtained by this method.

For preparative working chemists, the question of whether a specific solid can be created by chemical transport processes, which transport agents are suitable, and under what conditions a transport may be predicted is of paramount importance. If one simply wishes to employ transport reactions in a preparatory manner, rather than to fully comprehend the reaction's course, it is typically enough to check on an empirical basis which solids can be transported using which type of transport agent (Doubleday, 2007). Knowledge of the thermodynamic data of the condensed phases and gaseous molecules involved is required for a more quantitative description of the transport reaction. Thus, especially halogens and halogen compounds are qualified. Some elements, hydrogen compounds, and oxygen compounds are suitable as transportable species, too.

Chemisorption

Chemical adsorption, also known as chemisorption, is a process that occurs when adsorbate molecules form a chemical interaction with active sites on a material's surface. This contact is far more powerful than physical adsorption, or physisorption, which occurs on all surfaces at ideal temperature and pressure circumstances. Chemisorption, unlike physisorption, occurs exclusively on clean active sites and ends when the adsorbate can no longer make direct contact with the surface, making it a single layer process.

Chemisorption measuring techniques can be used to assess the physical and chemical properties of materials that are crucial to the process or reaction's success. Chemisorption is mostly used to determine the amount of accessible active sites in order to speed up or accelerate chemical reactions. Other qualities include the temperature at which catalysts become active (during reduction or oxidation), the strength of specific types of active sites, and the capacity of materials to perform following reduction/oxidation cycles (Chen and Yada, 2011).

Chemisorption measurements are critical for characterization of catalysts in a variety of industries, including oil and gas (e.g., petroleum refining, syngas conversions, biofuel production, fuel cells), petrochemicals, and fine chemicals (e.g., hydrogen production, polymers, and plastics production), environmental (e.g., automotive catalytic converters, green chemistry), and many others.

Static or dynamic flow methods can be used to conduct analyzes. The number of accessible active sites, active surface area, degree of dispersion, and active particle (crystallite) size can all be determined using any method of chemisorption at a desired temperature. The static approach can discriminate between strong and weak active sites, whereas pulse chemisorption is generally employed to investigate only strong active sites.

Non-isothermal techniques such as temperature-programed reduction (TPR), temperature-programed oxidation (TPO), and Temperature-Programed Desorption are accessible because industrial catalytic applications frequently entail fluctuations in reaction temperature (TPD). TPR measurements are used to assess reducible sites like metal oxides, whereas TPO measurements are used to assess oxidative sites like metals or carbonaceous deposits on catalysts. TPD (temperature programmed desorption) is a technique for determining the number, relative strength, and heterogeneity of active sites in solid or supported acid catalysts.

Composite

A composite material (also known as a composition material or composite, which is the popular word) is one that is made up of two or more constituent materials. These constituent materials have markedly different chemical or physical properties, and when combined, they form a material having features that are not found in the individual constituents. Individual constituents stay separate and distinct inside the finished construction, distinguishing composites from mixes and solid solutions (Bhattacharyya et al., 2009).

The following are examples of engineered composite materials:

- Masonry and reinforced concrete;
- Plywood, for example, is a composite wood;
- Fiber-reinforced polymer and fiberglass are examples of reinforced polymers;
- Composites with a ceramic matrix (composite ceramic and metal matrices);
- Advanced composite materials such as metal matrix composites and other advanced composite materials.

New material may be preferred for a variety of reasons. When contrasted to ordinary materials, examples include materials that are less expensive, lighter, stronger, or more durable.

Researchers have recently begun to actively incorporate sensing, actuation, computation, and communication into composites, dubbed robotic materials.

Natural or synthetic composites are available. Wood is a natural composite made up of cellulose (wood fibers) and lignin (a substance). Lignin is the matrix or natural glue that bonds and stabilizes the fibers, giving wood its strength. Other composites are made of synthetic materials (manmade).

Plywood is a composite material manufactured from natural and manmade components. Thin layers of wood veneer are adhered together with glue to make laminated wood sheets that are stronger than raw wood (Chauhan et al., 2012).

Boat hulls, swimming pool panels, racing car bodies, shower stalls, bathtubs, storage tanks, and imitation granite and cultured marble sinks and countertops are all examples of composite materials utilized in buildings, bridges, and constructions. They are also becoming more common in non-automotive applications.

The most advanced examples are used on spaceships and aircraft in harsh conditions on a regular basis. Concrete is the most common artificial composite material of all and typically consists of loose stones (aggregate) held with a matrix of cement. Concrete is an inexpensive material, and will not compress or shatter even under quite a large compressive force.

Computational Chemistry

Computational chemistry is a discipline of chemistry that employs computer simulations to aid in the resolution of chemical problems. It calculates the structures and properties of molecules, groups of molecules, and solids using theoretical chemistry methods included in computer algorithms. It is required because, with the exception of recent results involving the hydrogen molecular ion (dihydrogen cation; see references for more information), the quantum many-body problem cannot be solved analytically, let alone in closed form. While computational results are typically used to supplement information collected from chemical experiments, they can also be used to anticipate previously unknown chemical phenomes in specific situations. It is widely used in the design of new drugs and materials (Contreras et al., 2017).

Structure (i.e., the expected positions of the constituent atoms), absolute, and relative (interaction) energies, electronic charge density distributions, dipoles, and higher multipole moments, vibrational frequencies, reactivity or other spectroscopic quantities, and collision cross sections with other particles are examples of such properties.

The approaches utilized are applicable to both static and dynamic circumstances. Computer time and other resources (such as memory and disk space) increase significantly with the size of the system under study in all circumstances. This system might consist of a single molecule, a collection of molecules, or a solid.

Computational chemistry approaches range from very approximate to highly accurate, with the latter typically only being practical for tiny systems. Ab initio approaches are solely dependent on quantum physics and fundamental physical constants. Other methods are referred to as empirical or semi-empirical since they employ extra empirical parameters (Bowman and Hodge, 2007).

Approximations are used in both ab initio and semi-empirical techniques. These range from simplified forms of first-principles equations that are easier or faster to solve, to approximations that limit the system size (for example, periodic boundary conditions), to fundamental approximations to the underlying equations that are essential to reach any solution to them at all.

Copolymerization

A copolymer is a polymer composed of two or more monomer types. Copolymers are found in a wide range of commercially relevant polymers. Polyethylene-vinyl acetate (PEVA), nitrile rubber, and acrylonitrile butadiene styrene (ABS) are a few examples (ABS). Copolymerization is the process of forming a copolymer from numerous monomer species. It is frequently used to enhance or modify the characteristics of plastics.

A copolymer containing only a small fraction of a second monomer frequently has the desirable traits of the parent homopolymer, while the minor component provides the qualities that were previously lacking. Synthetic fibers manufactured from the homopolymer acrylonitrile, for example, offer great dimensional stability and resilience to weathering, chemicals, and microorganisms, but have a low dye affinity (Xia, 2008). The fiber Orlon is made by copolymerizing acrylonitrile with modest amounts of additional monomers, and it has the desirable properties of a homopolymer as well as the advantage of dyeability.

Crystallography

The experimental science of determining the arrangement of atoms in crystalline substances is known as crystallography (see crystal structure). The term “crystallography” is derived from the Greek words crystallon, which means “cold drop, frozen drop” and refers to all solids with some degree of transparency, and graphein, which means “to write.” The United Nations declared 2014 the International Year of Crystallography in July 2012, recognizing the importance of the study of crystallography.

Prior to the development of X-ray diffraction crystallography (see below), crystallography was dependent on physical measurements of their geometry with a goniometer (Figure 8).

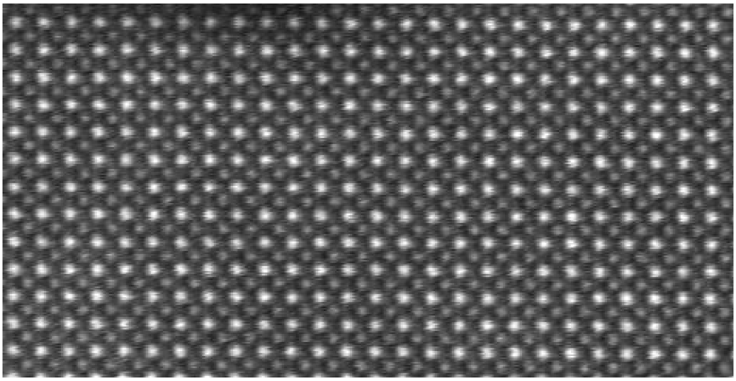


Figure 8. A crystalline solid: atomic resolution image of strontium titanate. Brighter spots are columns of strontium atoms and darker ones are titanium-oxygen columns.

Source: https://en.wikipedia.org/wiki/Crystallography#/media/File:Stohrem.jpg.

This entailed measuring the angles of crystal faces relative to each other and to theoretical reference axes (crystallographic axes) and determining the crystal's symmetry. Each crystal face's position in 3D space is mapped on a stereographic net, such as a Wulff net or Lambert net. On the net, the pole to each face is plotted. The Miller index is labeled on each point. The final plot establishes the symmetry of the crystal.

Crystallographic methods now rely on analyzing the diffraction patterns of a material that has been targeted by a beam of some kind. X-rays are the most widely used beams, but electrons and neutrons are also used (Weiss et al., 2020). The type of beam utilized is frequently stated clearly by crystallographers, as in the terms X-ray crystallography, neutron diffraction, and electron diffraction. These three forms of radiation have various interactions with the specimen:

- The spatial distribution of electrons in the sample interacts with X-rays;
- Because electrons are charged particles, they interact with the total charge distribution of the sample's atomic nuclei and electrons; and
- Neutrons are scattered by atomic nuclei due to strong nuclear interactions, but neutrons also have a non-zero magnetic moment. As a result, magnetic fields scatter them as well. Neutrons scatter

from hydrogen-containing materials, resulting in diffraction patterns with a lot of noise. However, the substance can sometimes be processed to replace hydrogen with deuterium.

Because of these different forms of interaction, the three types of radiation are suitable for different crystallographic studies.

Crystallography is one of the most significant procedures in helping us understand the world around us. It may not be the most well-known branch of science, but it is one of the most important techniques in helping us understand the world around us. Crystallographers can figure out practically anything's atomic structure. They then apply what they have learned to explain why things behave the way they do (West and Halas, 2000).

The science of crystallography explains why diamonds are so hard and lustrous, and why salt melts in your tongue. However, the approach is not limited to naturally occurring crystals. Almost any substance can crystallize. As a result, crystallography can be utilized to learn more about how the immune system combats infections. Robotic rovers could utilize it to look for signs of life in Martian soil samples.

D

Deoxyribonucleic Acid (DNA)

Deoxyribonucleic acid (DNA) is a kind of DNA. DNA is a molecule made up of two polynucleotide chains that coil around each other to create a double helix and carry genetic instructions for all known creatures and many viruses' formation, functioning, growth, and reproduction. Nucleic acids include DNA and ribonucleic acid (RNA). Nucleic acids are one of the four major types of macromolecules that are required for all known forms of life, alongside proteins, lipids, and complex carbohydrates (polysaccharides).

To produce double-stranded DNA, the nitrogenous bases of the two distinct polynucleotide strands are joined together with hydrogen bonds according to base-pairing regulations (A with T and C with G). Pyrimidines and purines are the two types of complementary nitrogenous bases. Thymine and cytosine are pyrimidines in DNA, while adenine and guanine are purines (Thompson, 2011).

The biological information is stored on both strands of double-stranded DNA. When the two strands separate, this information is reproduced. Non-coding DNA makes up a huge portion of DNA (more than 98% in humans), which means it does not serve as a pattern for protein sequences.

The two strands of DNA are antiparallel because they run in opposite directions. Each sugar has one of four types of nucleobases attached to it (or bases). The genetic information is encoded by the sequence of these four nucleobases along the backbone. In a process known as transcription, RNA strands are generated using DNA strands as a template, with DNA bases being exchanged for their equivalent bases except for thymine (T), for which RNA substitutes uracil (U). These RNA strands dictate the sequence of amino acids within proteins in a process known as translation, which is controlled by the genetic code.

DNA is organized into lengthy structures called chromosomes within eukaryotic cells. These chromosomes are replicated in the process of DNA replication before normal cell division, producing a complete set of chromosomes for each daughter cell. The majority of DNA in eukaryotic creatures (animals, plants, fungi, and protists) is stored in the cell nucleus as nuclear DNA, with some stored as mitochondrial DNA or chloroplast DNA. Prokaryotes (bacteria and archaea), on the other hand, only store their DNA in the cytoplasm, in circular chromosomes. Chromatin proteins, such as histones, compact, and order DNA within eukaryotic chromosomes. These compacting structures guide the interactions between DNA and other proteins, helping control which parts of the DNA are transcribed (Sozer and Kokini, 2009).

The DNA molecule's structure is extremely stable, allowing it to serve as a template for the replication of new DNA molecules as well as the synthesis of the related RNA (ribonucleic acid) molecule (transcription). A gene is a piece of DNA that codes for the cell's production of a certain protein.

DNA divides into two single strands, each of which serves as a template for a new strand. The same idea of hydrogen-bond pairing between bases that exists in the double helix is used to copy the new strands. Each of the two new double-stranded DNA molecules contains one of the original strands and one new strand. This "semiconservative" replication is the key to the stable inheritance of genetic traits.

Within a cell, DNA is arranged into chromosomes, which are dense protein-DNA complexes. Chromosomes are present in the nucleus of eukaryotes; however, DNA can also be found in mitochondria and chloroplasts. In prokaryotes, which lack a membrane-bound nucleus, DNA is present in the cytoplasm as a single circular chromosome. Extrachromosomal DNA, or plasmids, are autonomous, self-replicating genetic material found in some prokaryotes, such as bacteria, and a few eukaryotes. Plasmids have been widely utilized to research gene expression in recombinant DNA technology.

Viruses can have single-stranded or double-stranded DNA or RNA as their genetic material. Retroviruses contain their genetic material in the form of single-stranded RNA and create the enzyme reverse transcriptase, which can convert RNA into DNA. G-quadruplexes, four-stranded DNA structures, have been discovered in guanine-rich regions of the human genome.

Dual Use

"Biological research with genuine scientific aim, the results of which may be exploited to pose a biologic threat to public health and/or national security" is what dual-use research means in the life sciences. In general, the word refers to technologies that have both civilian and military applications. The dual-use research dilemma in the life sciences refers to the dilemma of producing and publishing research in the life sciences that is aimed at or intended to improve public health, animal health, or agricultural productivity, but could be used to harm public health if it falls into the hands of a rogue state, terrorist group, or individual (Smith et al., 2013).

Dual-use research of concern (DURC) is life sciences research that can reasonably be expected to provide knowledge, information, products, or technologies that could be directly misapplied to pose a significant threat to public health and safety, agricultural crops and other plants, animals, the environment, materiel, or national security, based on current understanding.

With the goal of promoting awareness and minimizing the potential for misuse of scientific information produced from life sciences research, the US government has released various policies pertaining to DURC.

Greater understanding of the smallpox virus led to the development of the first viral vaccination and the use of the virus as a bioweapon as early as the 18th century. The more tangible danger of bioterrorism has intensified fears and concerns about the performance and publication of dual-use research in the aftermath of the anthrax assaults of 2001 and heightened concerns about terrorism.

In the previous 50 years, scientists have deciphered the structure of DNA and sequenced the full genomes of 10 mammals (including humans, chimps, mice, rats, dogs, and cats), as well as other vertebrates, 6 invertebrates, 3 protozoa, 9 plants, and 14 fungi, as well as numerous viruses and bacteria.

Only 30 years ago, a doctoral thesis could take years to complete just to sequence one gene. In comparison, with today's technology, a single gene may be sequenced in a matter of hours. In 2002, a group of researchers published a paper explaining the three-year endeavor of synthetically reconstructing the poliovirus. The rebuilding of an equivalently large virus took only two weeks the next year. The exponential growth of sequencing and synthetic biology technology reflects a general increase in productivity and progress in the biological sciences.

Biotechnology, informatics, and automation have reduced the amount of work necessary and the time it takes to acquire knowledge while improving productivity and the number and sorts of topics biologists can address. The pace of biological discoveries and the emergence of new areas within biology is accelerated in unforeseen ways as a result of this convergence of biology and technology (Seil and Webster, 2012). Today's discoveries and inventions will lead to advancements in the next 30 years, and most likely in the following 5 to 10 years—discoveries and innovations that were not even conceived of at the time.

In politics, diplomacy, and export control, "dual-use" refers to technology that can be used for both peaceful and military aims.

More generally speaking, dual-use can also refer to any technology which can satisfy more than one goal at any given time. Thus, expensive technologies that would otherwise benefit only civilian commercial interests can also be used to serve military purposes if they are not otherwise engaged, such as the Global Positioning System.

Derivitization of Nanotubes

This invention relates to the preparation of chemical derivatives of CNTs as well as applications for the derivatized nanotubes, such as the formation of arrays as a basis for carbon fiber production. This invention also includes a method for making single-walled nanotubes (SWNTs) with substituents attached to their sidewalls by reacting SWNTs with fluorine gas, recovering fluorine derivatized CNTs, and then reacting fluorine derivatized CNTs with a nucleophile.

Nucleophilic substitution is used to replace certain fluorine substituents. If desired, the residual fluorine can be removed entirely or in part to create single-walled carbon nanotubes with substituents attached to the side walls. The substituents will, of course, be determined by the nucleophile, with alkyl lithium species such as methyl lithium being favored (Sawhney et al., 2008).

Researchers have been looking for ways to control SWNTs chemically since their discovery. While many papers and review articles have been published on the manufacture and physical features of CNTs, reports on chemical manipulation of nanotubes have been rare. Functionalizing nanotube ends with carboxylic groups and then manipulating them to tie them to gold particles via thiol linkages has been reported. Haddon and colleagues reported solvating SWNTs by adding octadecylamine groups to the tubes' ends and subsequently adding dichlorocarbenes to the nanotube sidewall, albeit in small amounts (2%). While theoretical results have suggested that functionalization of the nanotube sidewall is possible, experimental evidence confirming this theory has not been obtained.

Dispersion of Nanotubes

Carbon nanotubes (CNTs) have attracted wide attention because of their unique structure and properties. However, the prepared CNTs often present an agglomeration state, which destroys the excellent properties of single CNTs and seriously affects the dispersion of CNTs. How to effectively disperse CNTs has become an urgent problem to be solved. There are many factors affecting the dispersion of CNTs.

For incorporating multi-walled carbon nanotubes (MWCNT) into a resin-based on an aeronautical epoxy precursor cured with diaminodiphenylsulfone, different industrial mixing methods and some of their combinations: (i) ultrasound; (ii) mechanical stirring; (iii) by roller machine; (iv) by gears machine; and (v) ultrasound radiation + high stirring) were investigated (DDS). The impact of several parameters such as ultrasonic intensity, number of cycles, blade type, and gear speed on nanofiller dispersion was investigated (Sahoo and Labhasetwar, 2003).

The presence of the nanofiller in the resin generates a significant rise in viscosity, preventing the resin from homogenizing and causing a significant increase in temperature in the zones nearest to the ultrasound probe. To meet these obstacles, high-speed agitation was used in conjunction with ultrasonic radiation. This allowed for a more uniform dispersion on the one hand, and a better dissipation of heat generated by ultrasonic radiation on the other. The most efficient approach for preparing a carbon fiber reinforced panel (CFRP) with a mix of ultrasonic radiation and a high stirring method.

An appropriate dispersion of CNTs is a prerequisite for their use in improving the mechanical properties of cement-based composites. In this study, two types of CNTs having different morphologies were investigated.

To obtain a uniform distribution of CNTs in the cement matrix, the effect of sonication on the deagglomeration of CNTs in combination with anionic and nonionic surfactants in varying concentrations was quantitatively investigated when preparing aqueous dispersions of CNTs for the subsequent use in cement paste. The relationships between the quality of CNT-dispersion on the one hand and the sonication time and surfactant concentration on the other were determined using UV-Vis spectroscopy. After dispersion, nitrogen-doped CNTs were found mostly as individual, broken CNTs. In contrast, after the treatment of the mixture of single-, double-, and multi-walled CNTs, a net-like distribution was observed where destruction of the CNTs due to sonication could not be distinguished (Safari and Zarnegar, 2014). Modification of the cement pastes with dispersions of CNTs led to a pronounced increase, up to 40%, in compressive strength and, in some cases, to a moderate increase in tensile strength under high strain-rate loading. However, no significant improvement in strength was observed for quasi-static loading. Microscopic examination revealed that the bridging of the C–S–H phases differed depending on the type of CNT. This explained, at least partly, the observed effects of CNT-addition on the mechanical properties of hardened cement pastes.

DWNTs

DWCNTs are made up of two CNTs, one of which is embedded inside the other. The diameter and chirality discrepancies between the two nanotubes cause varying degrees of contact, yet the properties of the individual nanotubes remain independent. DWCNTs have piqued the interest of carbon nanotube researchers because of their wide range of possibilities. Because chirality controls whether a nanotube is semiconducting or metallic, varying chirality allows for a variety of inner-wall outer-wall interactions. Metallic-metallic, semiconducting-metallic, metallic-semiconducting, and semiconducting-semiconducting interactions are all feasible. Furthermore, depending on the specific lattice parameters, metallic and semiconducting properties can change, allowing for a large range of potential property combinations.

DWCNTs also have a significant advantage over single-walled carbon nanotubes in that the outer nanotube can be modified without affecting the inner nanotube's properties. This change could take the form of functionalization (the addition of solubilizing groups) or structural doping (to alter the properties). The double-walled system can maintain the functionality of a single-walled nanotube while still having the solubility of functionalized nanotubes. This combination makes double-walled systems appealing for use as composite material additives since it allows for large doping concentrations without altering the nanotube's overall capabilities (Ravichandran, 2010).

Synthesis and purification are the greatest roadblocks for DWCNTs in terms of further research and commercialization. For arc discharge, the yields generated by various synthesis processes can range from roughly 50% to 90%. Similarly, yields for catalytic chemical vapor deposition (CVD) might range from 70 to 85%. The remaining nanotubes made with these approaches are a combination of single-walled and multi-walled nanotubes that must be filtered to obtain individual double-walled nanotubes. Purification is a considerably more complicated process. Single-walled nanotubes are preferentially oxidized over double-walled nanotubes using methods such as high-temperature oxidation.

The method, on the other hand, has the potential to destroy the surviving nanotubes and leave multi-walled impurities behind. To obtain high-purity DWCNT samples and sort double-walled samples by outer diameter, further methods such as ultra-centrifugation can be applied. However, because this technique is labor-intensive and time-consuming, commercialization, and large-scale manufacture of high-purity DWCNTs is challenging.

Due to their amazing mechanical and electrical properties, DWCNTs, like single-walled carbon nanotubes, can be used in a variety of applications. The method, however, has the potential to destroy the surviving nanotubes and leave multi-walled pollutants behind (Presting and König, 2003). Other methods, such as ultracentrifugation, can be utilized to obtain high-purity DWCNT samples and sort double-walled samples according to their outer diameter. However, because this technique is labor-intensive and time-consuming, commercialization, and large-scale manufacture of high-purity DWCNTs are challenging.

Because of their amazing mechanical and electrical properties, DWCNTs, like single-walled carbon nanotubes, can be used in a wide range of applications. In addition, double-walled nanotubes show an increase in the mechanical strength, thermal stability, and also chemical stability over that of single-walled nanotubes.

Double-walled carbon nanotubes (DWNTs) are ideal candidates for supercapacitor materials because of their unique coaxial topologies and corresponding physical and chemical properties. However, hardly little research on DWNT-based composites for supercapacitor applications has been published.

DNA Dendrimer

Dendrimers are branching polymeric molecules with a high degree of organization. Arborols and cascade molecules are two synonyms for dendrimer. Dendrimers are usually symmetric around the center and have a spherical three-dimensional shape. The term dendron is also widely used. The focal point or core of a dendron is usually a single chemically accessible component. The distinction between dendrons and dendrimers is seen in the top picture, but the names are sometimes used interchangeably.

Divergent synthesis techniques were used by Fritz Vögtle in 1978, R.G. Denkewalter at Allied Corporation in 1981, Donald Tomalia at Dow Chemical in 1983 and 1985, and George R. Newkome in 1985 to create the first dendrimers. Craig Hawker and Jean Fréchet presented a convergent synthetic technique in 1990. Dendrimer popularity soared after then, with more than 5,000 scientific articles and patents published by 2005 (Porter et al., 2008).

Dendrimers are new polymeric architectures that have specified topologies, are versatile in drug delivery, and have high functionality. Their features are similar to those of biomolecules. By host-guest interactions and covalent bonding (prodrug method), these nanostructured macromolecules have demonstrated their prospective skills in entrapping and/or conjugating high molecular weight hydrophilic/hydrophobic substances. Furthermore, because of the high surface group to molecular volume ratio, they are a viable synthetic vector for gene delivery.

Dendrimers have attracted researchers in the development of new drug carriers due to their features, and they have been implicated in a variety of medicinal and biological applications. Despite their wide range of applications, their usage in biological systems is restricted due to toxicity concerns. In light of this, the current review has concentrated on the various strategies for their synthesis, drug delivery and targeting, gene delivery and other biomedical applications, interactions involved in the formation of drug-dendrimer complexes, as well as the characterization techniques used for their evaluation, and toxicity issues and associated approaches to mitigate their inherent toxicity.

Furthermore, these DNA dendrimeric nanocarriers are biocompatible, have a high intracellular transport efficiency, and are stable in a cellular context. This FNA dendrimeric nanocarrier could be used in a variety of biomedical diagnostic and therapeutic applications.

Dip-Pen Nanolithography (DPN)

Dip pen nanolithography (DPN) is a scanning probe lithography (SPL) technique that uses an atomic force microscope (AFM) tip to generate patterns directly on a variety of materials using various inks. The use of alkane thiolates to imprint into a gold surface is a common example of this approach. Surface patterning on scales of less than 100 nanometers is possible using this technology. The dip pen (also known as the quill pen) is a nanotechnology analog of the dip pen, in which the tip of an AFM cantilever functions as a "pen," which is covered with a chemical compound or combination acting as "ink," and placed in touch with a substrate, the "paper."

Dip-pen nanolithography (DPN) is an AFM-based patterning technique in which molecules are transported from a sharp tip to a surface. With DPN, the molecules to be deposited are first loaded onto the tip by dipping the tip into a melt or solution of the substance to be deposited (Patil et al., 2008). The atomically sharp tip is scanned in contact with a sample surface, similar to how a pen is used to write notes on paper. When the tip of the pen comes into contact with the surface, capillary forces caused by condensed water or melted ink move the ink molecules to the surface. Surface patterning with a feature size of less than 100 nm is typically possible with DPN.

DPN allows for the flexible deposition of nanoscale materials onto a substrate. Massively parallel patterning has recently been demonstrated utilizing two-dimensional arrays of 55,000 points.

This method has a wide range of applications in chemistry, materials science, and biology, including ultra-high density biological nanoarrays and additive photomask repair.

Jaschke and Butt were the first to report the uncontrollable transfer of molecular 'ink' from a coated AFM tip to a substrate in 1995, but they incorrectly concluded that alkanethiols could not be transferred to gold substrates to build stable nanostructures. A team of researchers led by Chad Mirkin at Northwestern University in the United States independently investigated the process and discovered that, under the right conditions, molecules could be transferred to a wide range of surfaces to form stable chemically-adsorbed monolayers in a high-resolution lithographic process they called "DPN." Mirkin and his coworkers hold the patents on this process, and the patterning technique has expanded to include liquid "inks." It is important to note that "liquid inks" are governed by a very different deposition mechanism when compared to “molecular inks” (Pathakoti et al., 2018).

DNA Cleavage

Only unmodified dsDNA is affected by ENase. The DNA cleavage occurs far distant from the recognition region, ranging from more than 400 bp to more than 7,000 bp. A loop-mediated translocation of DNA is most likely involved in the process of DNA cleavage at distant places on either side of the specificity site. The cleavage pattern is not completely random, but it is localized in a way that is most likely connected to structural properties of the DNA.

The cleavage takes place in two steps: first, the DNA is nicked in one strand, and then, a few seconds later, in the opposite strand at a point very close to the first.

It is a reaction that severs one of the covalent sugar-phosphate linkages between nucleotides that compose the sugar-phosphate backbone of DNA. It is catalyzed enzymatically, chemically or by radiation. Cleavage may be exonucleolytic – removing the end nucleotide, or endonucleolytic – splitting the strand in two.

A DNA structure is described that can cleave single-stranded DNA oligonucleotides in the presence of ionic copper. This “deoxyribozyme” can self-cleave or can operate as a bimolecular complex that simultaneously makes use of duplex and triplex interactions to bind and cleave separate DNA substrates (Nikalje, 2015). Bimolecular deoxyribozyme-mediated strand scission proceeds with a kobs of 0.2 min−1, whereas the corresponding uncatalyzed reaction could not be detected. The duplex and triplex recognition domains can be altered, making possible the targeted cleavage of single-stranded DNAs with different nucleotide sequences. Several small synthetic DNAs were made to function as simple “restriction enzymes” for the site-specific cleavage of single-stranded DNA.

Many biological activities, such as DNA replication, transcription, and recombination, rely on DNA cleavage. It can also be used for gene editing, pharmaceuticals, and biosensor development. Nanozymes’ goal is to create enzyme mimics made of nanomaterials. Nanozymes have higher stability, cheaper cost, and recyclability when compared to natural enzymes. Nanozymes with fascinating DNA cleavage activity, including both hydrolytic and oxidative cleavage, have recently emerged.

DNA Recognition

The recognition of specific DNA sequences by proteins is thought to depend on two types of mechanism: one that involves the formation of hydrogen bonds with specific bases, primarily in the major groove, and one involving sequence-dependent deformations of the DNA helix. By comprehensively analyzing the three-dimensional structures of protein-DNA complexes, here we show that the binding of arginine residues to narrow minor grooves is a widely used model for protein-DNA recognition. This readout mechanism exploits the phenomenon that narrow minor grooves strongly enhance the negative electrostatic potential of the DNA (Mnyusiwalla et al., 2003).

This effect is best illustrated by the nucleosome core particle. A-tracts, AT-rich sequences that exclude the flexible TpA step, are frequently related with minor-groove narrowing. These findings suggest that the ability to detect local variations in DNA shape and electrostatic potential is a general mechanism that allows proteins to achieve DNA-binding specificity by utilizing information from the minor groove, which otherwise provides few opportunities for the formation of base-specific hydrogen bonds.

Years of studying experimental constructions have shown two major contributions to the process of recognizing certain DNA sequences. Local interactions between the protein DNA-binding domain and the target base sequence, mostly in the form of a matching pattern of bidentate hydrogen bond donor and acceptor groups, are used in the base readout mechanism. Asparagine and glutamine can discriminate between the Hoogsteen edge of adenine and the other DNA bases, while these amino acids can recognize guanine specifically from the sugar edge. In addition, arginine recognizes guanine's Hoogsteen edge.

However, it was discovered that the local, linear model of DNA sequence recognition based on a complementary pattern of hydrogen bond donor and acceptor groups was insufficient. The readout of the nucleic acid structure can be equally, if not more, crucial in some protein—DNA complexes. In the contact zone, DNA frequently adapts non-canonical forms, and its proclivity to produce diverse local distortions is depending on a wider base sequence context (Morrow et al., 2007). High AT content narrows the minor groove, creating more negative electrostatic potential, a feature universally recognized by arginine side chains. GC-rich regions of the genome have a predisposition to adopt A-like conformations, while high AT content results in a narrowing of the minor groove, creating more negative electrostatic potential.

DNA Replication

During cell division, DNA replication is the process by which DNA duplicates itself:

- The initial step in DNA replication is to 'unzip' the DNA? molecule's double helix shape.
- This is accomplished by the helicase enzyme, which breaks the hydrogen bonds that hold the complementary bases of DNA together (A with T, C with G).
- A replication 'fork' is formed when two single strands of DNA are separated, forming a 'Y' shape. The two split strands will serve as templates for the creation of new DNA strands.
- This is the leading strand? One of the strands is oriented in the 3' to 5' orientation (towards the replication fork). This is the lagging strand, which is orientated in the 5' to 3' orientation (away from the replication fork). The two strands are copied differently as a result of their differing orientations (Figure 9).

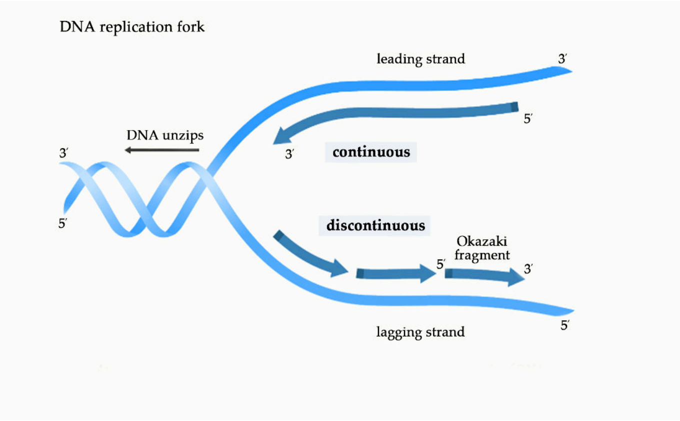


Figure 9. Replication of the leading and lagging strands of DNA.

Source: https://www.yourgenome.org/facts/what-is-dna-replication.

DNA replication is the biological process of making two identical replicas of DNA from a single original DNA molecule in molecular biology. All living organisms have DNA replication, which is the most important aspect of biological heredity. This is required for cell division during tissue growth and repair, as well as ensuring that each new cell receives its own copy of the DNA. The cell has the unique ability to divide, which necessitates the replication of DNA.

DNA is made up of two complementary strands that form a double helix. The double helix is the shape of a double-stranded DNA molecule, which is made up of two linear strands that run in opposite directions and twist together to form a molecule. These strands are split during replication (Mousavi and Rezaei, 2011). Semiconservative replication is the process of using each strand of the original DNA molecule as a template for the creation of its counterpart. The new helix will be made up of an original DNA strand as well as a newly synthesized strand as a result of semi-conservative replication. Cellular error-checking and proofreading systems ensure near-perfect DNA replication fidelity.

DNA replication begins in a cell at specified sites, or origins of replication, in the genome, which includes an organism's genetic material. Replication forks expand bi-directionally from the origin due to the unwinding of DNA at the origin and synthesis of new strands, which is facilitated by an enzyme known as helicase. The replication fork is connected with a variety of proteins that aid in the commencement and continuation of DNA synthesis. Specifically, DNA polymerase adds nucleotides that complement each (template) strand to create new strands. During the S-stage of interphase, DNA replication takes place.

In vitro DNA replication (DNA amplification) is also possible (artificially, outside a cell). To begin DNA synthesis at known sequences in a template DNA molecule, DNA polymerases isolated from cells and artificial DNA primers can be utilized. Examples include the polymerase chain reaction (PCR), ligase chain reaction (LCR), and transcription-mediated amplification (TMA). Researchers reported evidence in March 2021 that a preliminary form of transfer RNA (tRNA), a necessary component of translation, the biological synthesis of new proteins in accordance with the genetic code, could have been a replicator molecule itself during abiogenesis, the very early development of life (Mitter and Hussey, 2019).

DNA Structures

The information molecule is DNA. It contains the instructions for constructing other big molecules known as proteins. These instructions are stored in 46 long structures called chromosomes within each of your cells. These chromosomes are made up of thousands of genes, which are shorter fragments of DNA. The instructions for creating protein fragments, complete proteins, or numerous distinct proteins are stored in each gene.

Because of its molecular structure and the creation of a series of high-performance enzymes that are fine-tuned to interact with this molecular structure in specific ways, DNA is well-suited to execute this biological role. The match between DNA structure and the activities of these enzymes is so effective and well-refined that DNA has become, over evolutionary time, the universal information-storage molecule for all forms of life (Mei et al., 2011).

A molecule of DNA consists of two strands that form a double helix structure. DNA is a macromolecule consisting of two strands that twist around a common axis in a shape called a double helix. The double helix looks like a twisted ladder—the rungs of the ladder are composed of pairs of nitrogenous bases (base pairs), and the sides of the ladder are made up of alternating sugar molecules and phosphate groups.

Molecules of DNA range in length from hundreds of thousands to millions of base pairs. The smallest chromosome in the human genome, Chromosome 21, has around 48 million base pairs.

Each DNA strand is composed of nucleotides—units made up of a sugar (deoxyribose), a phosphate group, and a nitrogenous base.

Each strand of DNA is a polynucleotide composed of units called nucleotides. A nucleotide has three components: a sugar molecule, a phosphate group, and a nitrogenous base (Marcato and Durán, 2008).

The sugar in DNA's nucleotides is called deoxyribose—DNA is an abbreviation for DNA. RNA molecules use a different sugar, called ribose. Covalent bonds join the sugar of one nucleotide to the phosphate group of the next nucleotide, forming the DNA strand's sugar-phosphate backbone (Figure 10).

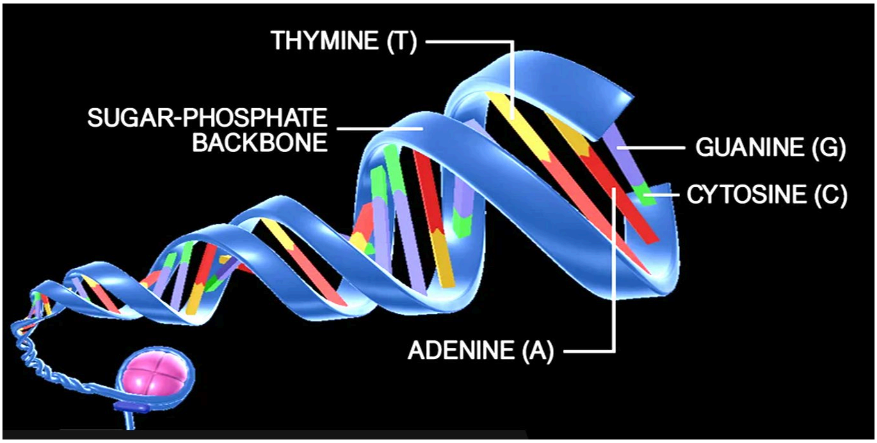


Figure 10. RNA molecules contain cytosine, guanine, and adenine, but they have a different nitrogenous base, uracil (U) instead of thymine.

Source: https://www.visiblebody.com/learn/biology/dna-chromosomes/dna-structure.

Drug Delivery

The method or process of providing a pharmaceutical substance to achieve a therapeutic effect in people or animals is referred to as drug delivery. Nasal and pulmonary routes of medication administration are becoming increasingly important in the treatment of human diseases. These methods, especially for peptide and protein therapies, offer intriguing alternatives to parenteral drug administration. Several medication delivery methods have been developed for this purpose and are being tested for nasal and pulmonary delivery. Liposomes, proliposomes, microspheres, gels, prodrugs, and cyclodextrins are only a few examples.

Nanoparticles made of biodegradable polymers have demonstrated their ability to meet the stringent requirements placed on these delivery systems, including the ability to be transferred into an aerosol, stability against forces generated during aerosolization, biocompatibility, targeting of specific sites or cell populations in the lungs, controlled drug release, and degradation in a reasonable amount of time.

E

Enabling Science and Technologies

Enabling science and technologies have broadly been used in the field of chemistry. Enabling technologies can be defined as tools or apparatus that can be used singly or alongside other technologies, creating the means to make significant leaps in user capabilities and performance. Enabling science and technologies have made it easy for chemists to make different kinds of molecules ranging from simple to very complex. Synthetic methods are used to develop these molecules. Chemists follow the principles of green chemistry. Few products are made using the principles. The principles state that it is better to prevent the creation of waste than cleaning up already created waste (Lü et al., 2009). However, for molecules to be created industries and academies need to work together. This way, the much-needed capacity is created that allows chemical transformations. It is also required that chemists and engineers work together more so in the early stages of research and development. This is because engineers are needed in designing chemical synthesis to be done. The more the collaboration, the higher the likelihood of success. Engineers and chemists have different approaches to solving issues. For this reason, more cross-talk is required between the two groups of people. Practices under green chemistry and engineering are similar to practices done by chemical engineers and chemists.

Enabling science and technology is mostly used in the medical field when dealing with bioinformatics. Bioinformatics deals with the study of information. This includes its use and structure. Bioinformatics deals with explaining how new information management techniques can be used to help in basic life sciences. Therefore, investigation is a vital element. The investigation process entails encoding knowledge of practice guidelines used in clinics. These guidelines are listed within computers as well as developing information technology. By so doing, the technology can interact with clinicians directly, enabling them to better offer health care services. Currently, researchers are working on a way to represent and store data in computers. The computer makes use of intelligent software systems able to interpret the outcomes of experimental data. It is also able to make automatic comparisons.

Enzymes

Enzymes are an essential part of our bodies. They are proteins in nature and play a vital role in speeding up metabolism as well as chemical reactions in the body. They are also involved in breaking down or building up substances. Enzymes are found in all living things. Similar to plants, human beings and animals can generate their own enzymes. Enzymes can also be artificially manufactured. Such kinds of enzymes are found in certain products and food. With regards to technology, synthesis of enzymes has been useful in treating a number of diseases. Take the case of Lysosomal storage disease. The disease encompasses chronic syndromes that go down from one generation to another. The disease causes a deficiency of certain enzymes in lysosomes. LSDs is said to cause death in serious cases. It also causes functional impairment and physical deterioration. The most effective mode of treatment for this disease is enzyme replacement therapy. This form of treatment gives patients the needed corresponding active enzymes. The challenge is that in blood, the enzymes do not have sufficient stability. For this reason, the treatment is given at a certain frequency and I.V infusion is used in administering the treatment. The treatment is done under medical supervision. The challenge with this treatment is that there are parts of the central nervous system where enzymes cannot reach due to the blood-brain barrier.

Nanotechnology is useful in dealing with the blood-brain barrier allowing the transportation of the enzymes towards targeted regions in the brain. Nanotechnology has created a way in which carriers are used to preserve and protect enzymes as they are transported within the body. Some of the strategies are formed on the basis of certain receptors in the blood-brain barrier. This resulted in nanoparticles being able to successfully carry certain molecules to the brain. More studies are underway to efficiently use nanotechnology in transporting enzymes to various parts of the body (Lieber, 2003).

Exploratory Engineering

Explanatory engineering involves one being able to comprehend potential technological capabilities. This includes trying to understand potential technological leaps in the future. It bears great similarities to the first stage of basic design engineering also known as conceptual design though they do not perform the same function. This is because, with explanatory engineering, one is able to illustrate how ideas though considered absurd could be visualized and enforced in the future while with standard engineering, developed designs results in the manufacture of products. There are extensive applications of explanatory engineering. There is a great need for definitive results in areas of mega-scale engineering, genetic modification, molecular engineering, and climate change. Fields of hypothetical molecular nanotechnology, bioethics, and climate engineering have been utilized in developing, examining hypotheses, defining limits and expression of potential solutions to expected technological issues. Those who support explanatory engineering look at the possibility of the generated solution being used in tackling the issues. Engineering is useful in developing or designing practical solutions to practical problems. To develop the solution, the scientist first looks at why the problem is there they proceed to do the much-needed research to answer the question. This is different for engineers. They are more concerned with how the problems can be solved. After they come up with the solution, they look at how they can implement it. Explanatory engineering presents the ideology that a well elaborate solution to a problem exists. It also looks at the putative characteristics of the solution while focusing on how the solution can be implemented. In a case where the implementation of the solution is made while adhering to the principles of engineering physics, then the activity changed from proto-engineering to actual engineering. This will determine the failure or success of the implemented design.

Epitaxial Film

Epitaxial film is a coating whose application is with a single crystal structure bearing relations to its substrate. The coating is thin in nature and the thickness measured in NM. Its application involves the use of atomic layer deposition (ALD). This film has formed the foundation of modern semiconductor technology. The technology has small nuances in its processing resulting in significant changes in the device performance. However, it is crucial that the properties of the subtle film are accurately measured. Structural properties of thin films are well characterized using XRD and Reciprocal Space Mapping. By using this technique, researchers, and engineers can measure lateral and perpendicular strain, domain effects and composition of the film (Lakhal and Wood, 2011).

When compared to bulk crystalline silicon, epitaxial materials are inherently freer of carbon impurities and oxygen. Among the advantages of epitaxial materials is the fact that they facilitate device fabrication that cannot be achieved by other methods. That gives direct options of creating abrupt and control changes in dopant profiles. It also allows the designer to control electron mobility through the creation of strained crystalline layers. This technique is referred to as bandgap engineering. Modification of these advantages have resulted in the use of silicon epitaxial layers. Silicon epitaxial layers have extensive applications, including being used to meet technological needs in semiconductor devices. Device designs that make use of abrupt dopant profile and controlled dopant profile changes are uniquely advantaged. For instance, bipolar devices can achieve higher switching speeds through the use of epitaxial layers in controlling dopant profiles. It also lowers base resistance, enhances high voltage operation and linearity, and makes isolation schemes much easier. The use of epitaxial layers has different effects. For instance, with MOS devices it can lead to reduced diffused-line capacitance, improved dynamic of the Random-Access Memory, improved resistance to static charge and aloha particle damage and improved diffused-line charge retention. For CMOS devices, the use of epitaxial silicon layers is said to enhance latch-up protection. Different doping profiles utilized in modern device fabrication can be achieved by using Vapor Phase Epitaxial silicon. Some of the doping profiles include the p-type silicon over n-type silicon, n-type silicon over p-type silicon, conducting silicon on insulator, lightly doped over heavily doped layers and silicon layers with controlled profiles.

Electrochemical Methods

Electrochemical methods are also called electrochemical techniques. These methods include chronoamperometry, cyclic voltammetry and potentiometry. Electrochemical methods fall in the same group as Voltammetric methods. They are used in analyzing the impendence of different electrochemical systems. Knowledge of electrochemical processes is vital, more so in the field of nanotechnology. For this reason, a number of studies are done in electrochemical processes and materials (Klimeck et al., 2008). The electrical conductivity of an electrochemical system is influenced by external parameters and their properties. The extent to which the parameters affect parameters affect electrical conductivity of electrochemical system, the impendence is measured. The resultant measured data gives information for a pure phase. A pure phase could mean the mobility of equilibrium concentration of charge carriers, dielectric constant, or electrical conductivity.

Electrochemical Properties

Electrochemical properties are defined under electrochemistry. Among the properties of molecules is their electrochemical properties. The same applies for materials used in nanotechnologies. For various kinds of materials, the microstructures such as their composition, defects, and crystallinity are essential in determining their properties. This determines the extent to which the materials can be used. By controlling the microstructures of various materials has led to cubic silicon carbide films being engineered. The electrochemical properties of the films influence the engineering. Other elements that can be manipulated to achieve different properties of cubic silicon carbide films include epitaxial, microcrystalline, nanocrystalline (NC), and deposition conditions. Based on the electrochemical performance of the film, its uses can be classified into two. An electrochemical dopamine sensor using the film or an electrochemical capacitor that uses a NC film.

Electroluminescence (EL)

Electroluminescence (EL) is an electrical and optical phenomenon by which materials emit light as a result of the flow of electric current or due to the presence of a strong electric field. This form of light emission is not the same as light emission due to heat, a phenomenon known as incandescence, sonoluminescence, chemiluminescence or blackbody light emission as a result of mechanical action. Electroluminescent instruments are made using inorganic or organic electroluminescent materials. Of these materials, those considered active are said to be semiconductors with an appropriate bandwidth that allows exits of the light. The most common type of electroluminescent material made using inorganic thin EL material is zinc sulfide. For this material, the emission is yellow-orange in nature. Other examples include semiconductors having Group III and Group V are light-emitting diodes. They include gallium nitride, gallium arsenide and indium phosphide. Other EL material is the naturally occurring blue diamond having traces of boron to play the role of a dopant, thin-film zinc sulfide doped with manganese and powdered zinc sulfide doped in silver to produce a bright blue light or doped in copper to produce light greenish in nature (Figure 11) (Arora et al., 2014).

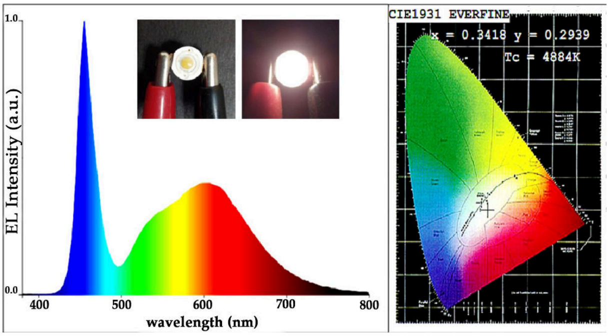


Figure 11. Electroluminescence involves the emission of light my materials.

Source: https://www.researchgate.net/figure/Electroluminescence-EL-spectra-left-and-corresponding-Commission-Internationale-de_fig6_282965383.

It is important to note that EL is brought about by radiative recombination of holes and electrons in a material more so a semiconductor. When an electron is in its excited state, it loses electron releases energy as photons of light. Before the recombination, holes and electrons can be separated through the excitation of high-energy electrons accelerated towards a target by a strong electric field as observed in electroluminescent displays with phosphors or by doping the material resulting in the formation of a p-n junction. Studies show that solar cell improve light-to-electricity efficiency. This implies that the open-circuit voltage is improved. It is expected that the same could be expected for electricity-to-light efficiency.

Electron Diffraction

Electron diffraction is the process in which beams of electrons are diffracted by molecules or atoms. It can also be defined as the technique used in studying matter by having electrons fired at a sample and the resulting inference pattern is observed. Electron diffraction is mostly used when determining crystal structure. Electrons are waves in nature. Electron diffraction is based on a phenomenon known as the wave-particle duality. It states that a particle can be described as a wave. Therefore, an electron can be considered as a wave. Electron diffraction is similar to neutron diffraction and X-rays. This technique is mostly used in chemistry when studying the crystal structure of solids and solid-state physics. Scanning electron microscopes and transmission electron microscopes are used during experiments as electron backscatter diffraction (Figure 12).

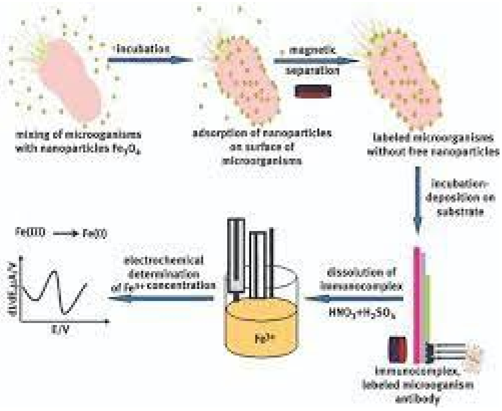

incubation
magnetic separation
mixing of microorganisms with nanoparticles Fe_3O_4
adsorption of nanoparticles on surface of microorganisms
labeled microorganisms without free nanoparticles
incubation-deposition on substrate
Fe(III) → Fe(0)
dI/dE, μA/V
E/V
electrochemical determination of Fe³⁺ concentration
Fe^{3+}
dissolution of immunocomplex
$HNO_3+H_2SO_4$
immunocomplex, labeled microorganism antibody

Figure 12. The transmission electron microscope is used in electron diffraction.

Source: https://www.researchgate.net/figure/Electron-diffraction-patterns-of-G-phases-in-the-ternary-systems-Ti-Fe-Al-a-b-Ti-Co-Al_fig1_240414675.

Electrons are accelerated to gain desired energy by an electrostatic potential. The wavelength of the electrons is then determined, and finally, the electrons are allowed to interact with the sample being studied. Electron diffraction is used is studying the crystal structure of solids because the periodic structure of crystalline solids acts as diffraction grating. This means that electrons will be scattered in a particular manner as predicted by chemists. Once a diffraction pattern is obtained, the chemist can work back and able to determine the structure of the crystal. Though the technique works, it is not as effective due to a phase problem (Abolmaali et al., 2013). Another challenge is the fact that the sample to be studied should be electron transparent to allow electrons to pass through it. For this reason, it is advisable that the sample have a thickness of 100 nm or less. Other than studying electron crystallography, electron diffraction is also used in studying the short-range order of imperfections, short-range ordering of vacancies, and short-range order of amorphous solids and the geometry of gaseous molecules.

Electron Microscopy

Electron microscopy is a method used in getting high resolution images of both biological and non-biological specimens. This technique is extensively used in biomedical research when investigating the detailed structure of macromolecular complexes, organelles, cells, and tissues. Electron microscopy images are high resolution images of the use of electrons with relatively short wavelengths. The electrons are used as the source of the illuminating radiation. The techniques are used together with different ancillary techniques in answering specific questions. Some of these techniques include negative staining, immune-labeling, and thin sectioning. The high-resolution images produced through electron microscopy give vital information on the structural basis of cell disease and cell functions. The device used for electron microscopy is known as an electron microscope. There are two types namely the scanning electron microscope and the transmission microscope. When dealing with thin sections of tissues and molecules, the transmission electron microscope is used. The specimen is viewed when electrons pass through the specimen and projects the image of the specimen. The working of a transmission microscope is almost similar to the working of a compound microscope. It is used to image the organization of molecules cytoskeletal filaments and viruses. In this case the image is generated by utilizing the negative straining technique. Other than that, the transmission electron microscope is used to produce an image of the structure of protein molecules and interior of cells. By freeze-fracture, the transmission microscope is used in imaging the arrangement of protein molecules in the cell membrane.

Different from the transmission electron microscope, the scanning electron microscope is used depending on whether secondary electrons have been emitted from the surface of a specimen. Focusing done by the scanning electron microscope is of greater depths. The scanning electron microscope is considered the electron microscope analog of the stereo light microscope. Images produced the scanning electron microscope are more detailed compared to those produced by a transmission electron microscope. It can capture images of whole organisms. It is also used in process control, size determination and particle counting. The name scanning microscope is due to the fact that the image is generated by scanning a focused electron beam onto the specimen's surface. The focusing is done based on a particular pattern (Kung and Kung, 2004). As the atoms near the surface interact with the primary electron beam, the interaction lead to the emission of particles in every point in the raster. Some of the produced particles include photons, x-rays, high energy backscatter electrons and low energy secondary electrons. By using different detectors, the produced particles can be collected. Once collected their relative number is translated to brightness at each of the points.

Electron Transfer

Electron transfer is said to occur when an electron moves from one molecule to another or one atom to another. Electron transfer is characteristic to redox reactions where both the oxidation states of reactants and products change. Electron transfer reactions occur in a number of biological processes. The biological processes include detoxification, respiration, photosynthesis, and oxygen binding. Energy transfer processes can be explained as a two-electron exchange where two concurrent electron transfer processes occur in opposite directions when the distance between the transferring molecules is relatively small. There are different classes of electron transfer. The classes are defined by the connectivity of the two redox centers and the state of the two redox centers. The classes include the heterogeneous electron transfer, outer-sphere electron transfer and the inner-sphere electron transfer. The heterogeneous electron transfer involves an electron moving between chemical species and solid-state electrodes. The inner-sphere electron transfer involves the two redox centers being covalently linked during the electron transfer process. The linkage between the two redox centers is considered a bridge. When the bridge is permanent, the process of electron transfer is now referred to as intramolecular electron transfer (Kaur et al., 2014). This may not be the case for all molecules. Usually, the bridge is temporary. In this case, the link between the two redox centers is established before electron transfer occurs. The outer-sphere electron transfer is different from the inner-sphere electron transfer in that there is no bridge established between the two redox centers. This means that electron transfer occurs in the absence of a bridge. Electron transfer occurs by the electron hopping through space from the reducing center to the acceptor center. Outer-sphere electron transfer occurs between chemicals species having different oxidation states. When the exchange occurs between identical chemical species, the process is referred to as self-exchange. The exchange can also occur between different chemical species. A significant number of theories have been developed to try and explain the different types of electron transfer processes.

Electron Transport

Electron transport is the transport of electrons from one molecule or atom to another. Electron transport is usually conducted by an electron transport system. The transport process takes the form of a chain. Electron transport is said to occur in molecular junctions. Among the goals of nanotechnology is building an electronic device that uses individual molecules. For this to be achieved, it is essential that electron transport through molecules is measured, controlled, and understood. Other than the body, electron transport can also occur in nanostructures and semiconductors.

Electron Tunneling

Electron tunneling in relation to nanotechnology is studied under the field of quantum mechanics. If a barrier (potential barrier) is placed in the path of electrons would hinder the flow of electrons. This is according to classical physics. However, if the barrier is reduced and made too thin, then electrons will be able to tunnel through the barrier as a result of quantum mechanics effects. Flow of electrons through the barrier is affected by the width of the barrier and its height. As electrons are considered to be waves, electron tunneling results in the disappearing of a wave on one side and its re-appearance on the other side. Electron tunneling is said to occur between barriers of thickness ranging from 1 to 3 nm.

Electro-Optics

Electro-optics refers to the branch of science that studies how light and optical properties of substances are affected by electric fields. It therefore deals with systems, devices, and components that operate on the basis of interaction and propagation of light with a variety of tailored materials. Some of the devices that work on this basis include waveguides, LEDs, and lasers. Electro-optics can be related to photonics as it involves the interaction between electrical and electromagnetic states of materials. To better understand electro-optics, it is important that one has knowledge on the basics of electromagnetism. Various electro-optic technologies have been developed to help in the supply of enabling components and diagnostic equipment globally. They play crucial roles in industries and in laser systems (Kandel et al., 2013).

Electrophoresis

Electrophoresis is a method used in laboratories in the separation of RNA, DNA, or protein-based molecules. The separation is done based on their electrical charge and size. The electric charge is useful in allowing the use of electrical current to move the molecules through a gel. This method of separation is effective because the gel has pores that act as a sieve. Small molecules move through it faster compared to those of relatively larger sizes. Depending on the size of molecules to be separated, conditions used during electrophoresis can be modified accordingly. Electrophoresis is a broadly used technique with extensive applications ranging from forensics when determining identities of criminals through the linkage of their DNA patterns and their electrophoresis patterns. Electrophoresis of anions (negatively charged particles) is known as anaphoresis while electrophoresis of cations (positively charged particles) is also known as cataphoresis.

Encapsulation

Encapsulation in the process in which data is wrapped up into a single unit. This mechanism puts together data that it manipulates and codes. Encapsulation can also be explained as a protective shield that hinders access of data by the code outside the shield. Encapsulation is mostly linked to computer programs such as java. Data encapsulation is very important. Encapsulation involves data or variables of a certain class being hidden from other classes. The data can only be accessed through the use of member functions of the class in which it was declared. Encapsulation makes use of the concept of data hiding which is attained by ensuring that methods and members of the private class. By so doing, the data is hidden from other classes and though the class is exposed to the world or end-user while ensuring that details of the implementation using abstract concepts are not given to other users. This is referred to as the combination of abstraction and data-hiding (Huang et al., 2010). Declaration of all the variables in the class as writing public and private methods in the class to get and set the values of the variables brings about encapsulation. Among the advantages of encapsulation is data hiding where users have no knowledge of the inner implementation of the class. It also increases the flexibility and re-usability of data in the given class. This is very essential in the field of nanotechnology.

Epitaxy

Epitaxy is a term derived from the Greek word epi and taxis. The term epi means above while taxis mean in ordered manner. The term can generally be translated as “to arrange upon.” Therefore, Epitaxy can be used to refer to the deposition of an over-layer on a crystalline substrate. It is important that the over-layer in one registry with the substrate. The over-layer is also known as epitaxial layer or epitaxial film. The advantage of epitaxy is that it is an elemental source can be switched almost instantaneously. It is also scale-able in the production of significantly high-volume. The disadvantages of epitaxy are that it is difficult to continuously meter sources, it is also quite hard to incorporate high vapor-pressure source and highly complex apparatus are needed.

Excited States

The excited state is a quantum state of a molecule or an atom at a higher energy than the ground state. To better understand spectroscopy, it is important for one to have knowledge and understanding of excited states as well as their relaxation while at low energy states. Excited states play a central role in photochemistry. Electrons usually exist at an arbitrary baseline energy state. However, when electrons are at an excited state, they are at a higher energy level which is above the arbitrary baseline energy state (Gunasekaran et al., 2014). Particles at a higher energy state tend to have a particular temperature. This means that temperature can be used to indicate the level of particle excitation. This however is in exception of systems that portray negative temperature. Metastable is the term used to refer to cases where particles stay in long-lived excited states. In most cases, the excited states last for short durations.

F

Fullerenes

Fullerenes is a form of carbon consisting of a spheroidal molecule that has a hollow cage o more than 60 atoms. It is the said to be the third form of carbon alongside diamond and graphite. Fullerenes is also referred to as buckminsterfullerene. The hollow carbon molecules put together to form a closed cage are referred to as buckyballs or carbon nanotubes (CNTs). Fullerenes were first discovered by Sir Harold W. Kroto in 1985. Harold worked alongside a group of scientists. They used lasers to vaporize graphite rods in a surrounding filled with Helium gas. They were able to obtain cage like molecules made of 60 carbon atoms put together by single or double bonds. The single and double bonds form a sphere with 20 hexagonal and 12 pentagonal faces. Its structure resembles a soccer ball. Carbon 60 has a highly symmetrical shape. Other than the hollow shape, fullerenes molecules can also take the shape of the tube and ellipsoid. They also have different sizes. The empirical formula of the carbon molecules is used in the informal denotation of fullerenes having a closed mesh topology. The empirical formula written as Cn where n represents the number of carbon atoms. In some special cases, values of n can be more than one isomer (Gupta, 2011). Fullerenes got its name from buckminsterfullerene which is then refined to be Buckminster fuller. Bucky onions is the name given to nested closed fullerenes while CNTs are the name given to cylindrical fullerenes. They are also referred to as buckytubes. Fullerite is the name given to the bulk solid for mixed or pure fullerenes. The discovery of fullerenes led to other allotropes of carbon. Fullerenes has been used alongside other technological applications and has now been used in nanotechnology. There two main families of fullerenes. The difference between the two families is brought about by their applications and distinct properties. For the buckyballs they are closed in nature while cylindrical CNTs are opened-ended. With further research, hybrids of fullerenes have been created. They are between CNTs and buckyballs. The hybrid class is known as carbon nanobuds. The carbon nanobuds is made up of nanotubes capped by hemispherical meshes.

The smallest fullerene molecule is known as the buckminsterfullerene having hexagonal and pentagonal rings. In their structure, two pentagons do not share as edge. Such a structure is considered dis-stable. This kind of structure naturally occurs in chemical compounds such as soot. The truncated icosahedron is the structure of the buckminsterfullerene. 1.1 nanometers is the Van der Waals diameter of a buckminsterfullerene molecules. The molecules also have two bond lengths. For ring bonds of 6 to 6, they are referred to as double bonds. This is between two hexagons while those with the ratio of 6 to 5 the bond between a pentagon and a hexagon (Farokhzad and Langer, 2009). As described earlier, CNTs have cylindrical fullerenes and have a very few nanometers (NMs) wide. These CNTs can either be open-ended or closed-ended. It has a very unique molecular structure. They have a relative chemical inactivity, high heat conductivity, high electrical conductivity, high tensile strength, and high ductility.

Functionalization of Nanotubes

Functionalization of nanotubes is also referred to as the modification of CNTs, decoration of CNTs, and chemistry of CNTs and filling of CNTs. Functionalization of nanotubes is made of the attachment of either inorganic or organic moieties in their tubular structure. The functionalization of CNTs has allowed for the modulation of their physicochemical properties, improve their process-ability, manipulation, and improve their ease of dispersion. Different techniques can be used when modifying CNTs. The techniques can be categorized into four major groups. They are endohedral filling, external decoration with inorganic materials, non-covalent functionalization, and covalent functionalization. One or more graphene layers are rolled up to form a cylinder which is then referred to as a carbon nanotube. The graphene layer is composed of a sp2 hybridized carbon atom part of a hexagonal network. Among the different types of CNTs is the single-walled carbon nanotube. They are known for their novel properties like the ease of cellular uptake and nano-scale size. This attribute makes them very useful in drug delivery. CNTs also have good photo-thermal effects that allows their extensive application in different areas including the treatment of solid tumors. Carbon tubes are similar to graphene as their materials are made of pure carbon. They have an extended conjugated π-network which gives them their extraordinary quantum optoelectronic properties. Though the π-network is advantageous, it presents its own limitations. The quantum properties could be blurred as a result of the π-π staking interaction. This interaction results in the production of tubes bundled together.

The main goal of the functionalization of carbon tubes is to allow the modification and protection of tubes by ensuring that π-π does not occur. Numerous functionalization strategies have been developed and adopted to deal with the π-π staking problem. This will allow the extensive applications of nanotubes. The developed strategies place much emphasis on the balance between the preservation of tube properties and the functionalization efficacy. For this to be achieved, much focus is placed on ensuring that the strategy will overcome the covalent and non-covalent dichotomy. This will then allow the implementation of two main functionalization schemes (Ehdaie, 2007). Plasmonic nanosystems and conjugation with molecular switches are the two functionalization schemes. Plasmonic nanosystems allow the concentration and enhancement of electromagnetic fields resulting in improved optical response of the tubes. Conjugation with molecular switches bring about hybrid nano-systems having chemo-physical properties which can be tuned in a reversible and controlled manner.

Ferroelectrics

Ferroelectrics is commonly referred to as ferroelectricity. It is defined as the process by which specific materials exhibit dipole movement spontaneous in nature. Relative shifts in negative and positive ions cause an induction in surface charges which causes ferroelectricity. Ferroelectrics is also said to occur when certain materials exhibit sudden electric polarization. Materials that exhibit ferroelectricity are referred to as ferroelectric materials. These materials are used in making capacitors with actuators, transducers, and a high dielectric constant. For such a material, the direction of polarization can be changed to equivalent states by applying an external electric field. There are certain conditions to be met for ferroelectric materials to exhibit sudden polarization. Among the requirements is that the materials should be in an area where temperatures are below the Curie temperature. This means that for spontaneous polarization to occur, the ferroelectric material should be at a temperature below the curie-temperature. When an electric field exceeding the coercive field is applied, the direction of polarization will be reversed. When the applied field is zero, the ferroelectric material is said to exhibit a sudden non-zero polarization. The electric dipole movement is called polarization and ferroelectricity is a product of polarization. Both ferroelectric and dielectric are different in that ferroelectrics are composed of crystalline substances and exhibit permanent sudden electric polarization which is different dielectrics. Dielectric is called an electric insulator that may be polarized when an electric field is applied. They are also able to store electrical energy. When a dielectric is used and a field is applied, both the positive and negative charges get separated in different directions resulting in the creation of an electric dipole in the material.

When discussing about ferroelectrics, we come about ferroelectric crystals. The ferroelectric crystal is a crystal having ferroelectric properties. As a ferroelectric crystals are ferroelectric materials, they exhibit spontaneous dipole movement. This means that they experience relative shifts of negative and positive ions. When a ferroelectric material is placed between two conductive plates, it results in the creation of a ferroelectric capacitor. Ferroelectric capacitors have a high dielectric constant and non-linear properties. Application of an external voltage results in the internal electric dipole being forced to change their direction. This brings about hysteresis in the polarization. These ferroelectric capacitors are known to have different properties including pyro-electricity, piezoelectricity, and memory. These properties make ferroelectric capacitors a very significant technological tools used in medical ultrasound machines, vibration sensors, sonar, fire sensors and high-quality infrared cameras (Doubleday, 2007).

The applications of ferroelectric materials are extensive. They include then being used in the manufacture of a capacitor. The capacitor is formed using barium titanate. They can also be used in waveguides. These devices are used in controlling the propagation of light. The materials are also used in the display of optical memory. One advantage of ferroelectric material is that they are more reliable and cheaper.

Ferro-Fluid

Ferro-fluids are liquids that become highly magnetized when placed in a magnetic field. When placed in a magnetic field, ferrofluids develop a unique spikey shape. The shape comes as a result of the need for the fluid to find the most appropriate shape while in the magnetic field to reduce the total energy of the system. This phenomenon is referred to as the normal-field instability. When a fluid is in a system having air and a magnetic field is introduced, the fluid is easily magnetized compared to the surrounding air, which is drawn out along magnetic field lines. This leads in the formation of troughs and peaks. It is important to note that surface tension and gravity resists the extension of the ferro-fluid. The magnetic energy of a system is lowered due to the formation of the corrugations. Formation of corrugations causes the space free energy and gravitational energy to increase. For minimum energy configurations to be achieved the forces involved have to be balanced. A small bar magnet can be used to produce peaks in a ferrofluid. This is because they have a significant magnetic susceptibility. Ferrofluids have nano-scale ferromagnetic particles and are therefore referred to as colloidal fluids. In ferrofluids, the ferromagnetic particles are suspended in a carrier fluid (Chen and Yada, 2011). Ferrofluids are composed of 85% carrier fluid, 10% surfactant and 5% magnetic particles. The magnetic particles are 10 nanometers in diameter. The particles are said to be magnetic because they contain hematite or magnetite, which is a highly magnetically susceptible compound. To allow even distribution of the particles in the fluid, the particles are small in size. Their dispersion in water is through the Brownian motion. Though the particle size is small, the size is not small as their size determines their ability to contribute to magnetic responses of the fluid. The nanoparticles get aligned with the field when an external magnetic field. When the field is suddenly removed, the particles will resume their initial random alignment. This results in ferrofluids being referred to as superparamagnets and not ferromagnets.

Magnetic nanoparticles in ferrofluids do not aggregate in the carrier fluid due to the surfactant's Van der Waals forces. Though surfactants are different, they all follow the principle that the surfactant generates a layer around the particle that in turn repels other coated nanoparticles. This means that the presence of a surfactant is very crucial. However, the presence of a surfactant causes a reduction in the viscosity of the fluid while in the magnetized state and thus said to be soft. This is a challenge as most applications of ferrofluids require it to be a hard fluid. This attribute is considered to be very important when selecting the composition of ferrofluid. Other properties of ferrofluids are that they exhibit high thermal conductivity as well as heat transfer properties. These properties are utilized in devices as such as loudspeakers where the fluid is used in cooling the voice coil. Other than being used in speakers, currently more research is underway to check the possibility of ferrofluids being used in the medical field. Some of the applications of ferrofluids in the magnetic field is magnetic drug targeting. It involves the ferrofluid enclosing a drug which when injected to the targeted area, a magnetic field could be used to ensure that the drug remains in the targeted area. This technique of drug administration is advantageous as other parts of the body will not be exposed to drugs and also help lower the dosage level minimizing the severity of the drug's side effects.

Ferromagnetic Materials

Ferromagnetic materials are materials that at the atomic level exhibit a sudden net magnetization in the presence or absence of an external magnetic field. Ferromagnetic materials exhibit ferromagnetism which is the strongest form of magnetism. Ferromagnetic materials become strongly magnetized when an external magnetic field is introduced. They get magnetized in the direction of the magnetic field. The magnetic properties of ferromagnetic materials make them strongly attracted to magnets. One notable property of ferromagnetic materials is that they are able to retain the magnetization for a significant duration of time even after the external magnetic field is removed. This attribute is referred to as hysteresis. Ferromagnetic materials can also be described as materials that display or manifest relatively strong magnetism when an external field is applied and the magnetism occurs in the direction of the magnetic field. Magnetism in ferromagnetic materials is brought about by the alignment patterns of atoms in the material. For this reason, the atoms function as elementary magnets.

Most metals can be classified as ferromagnetic materials. Some ferromagnetic materials include nickel, cobalt, iron, metal alloys, and rare earth magnets. One common ferromagnetic material is magnetite. It is formed when iron is oxidized into an oxide. Initially, magnetite was considered a magnetic material. When compared to other naturally occurring materials magnetite is said to exhibit the strongest magnetism. Ferromagnetic materials are known for their properties which include its atoms having a permanent dipole in its domains. For ferromagnetic materials, their atomic dipole moment tends to be oriented in the direction of the external magnetic field. Besides the fact that magnetism occurs in the direction of the external magnetic field, the magnetic dipole moment is also significantly large (Chauhan et al., 2012). The amount of saturation in ferromagnetic material is said to be dependent on the nature of the material. This is explained by the fact that the intensity of magnetism is positive and large. The same applies to the magnetic susceptibility. The relationship between the magnetizing fields is linear. Ferromagnetic materials are also said to lose their ferromagnetic properties when liquefied. A strong force of attraction is noted between ferromagnetic materials and an external magnetic field. Within a ferromagnetic material, magnetic field lines are very dense while its magnetic flux density will be positive and large. The relative permeability and the magnetizing field vary linearly with the relative permeability being considerably large.

Field Effect

Field-effect is a phenomenon used to refer to the use of an external electric field in the modulation of electrical conductivity of a substance. An external electric field can penetrate through a material over short distances because of the large electron density responding to the applied external field. This is not the case for semi-conductors as the electron density responding to the applied external electric field is relatively small. As the density is relatively small, the external electric field can penetrate further into the material. The conductivity at the surface of a semiconductor is affected by field penetration. This phenomenon is referred to as field effect. Operation of the field-effect transistor and Schottky diode is influenced by field effect. When compared to conductors, semi-conductors have a smaller number of free electrons. For this reason, the amount of current flowing through a semiconductor is fair as current flow is dependent on free electrons. If a silicon slab is placed at the center of a circuit, the current will stop flowing. However, if an electric field is introduced in the presence of silicon, a change will be noted. If a metal plate (positively-charged) is introduced near the circuit, it will attract the negatively-charged electrons within the semiconductor (Contreras et al., 2017). This results in electrons streaming on the surface, bringing about an abundance of free electrons. If the passage is stopped, flow of electricity will occur. Current flowing through a semiconductor can be easily flipped off and on by controlling the voltage on the metal plate. Signal sent to a metal plate is similar to the current flowing through a semiconductor. The slight difference is that the signal is a bit larger. This is because the original signal is amplified by an amplifier. The working of the used transistor will dependent of the electric field therefore the transistor is referred to as a field-effect transistor.

Field Emission

Field emission is a phenomenon where electrons tunnel from the surface of a semiconductor into a vacuum in the presence of a high electrostatic field. Field electron emission has been noted among semiconductors and metals. Field emission has been systemically studied in ultrahigh vacuum conditions. The results of the study led to the development of the technique field emission microscopy. The study of surface diffusion of adsorbates when placed on clean metal surface are among the significant applications of field emission in surface science. During the study, the emitter was uniformly covered with an adsorbate while utilizing the initial FEM technique, current will emanate from a very small region of the emitter's surface. The current is measured. The technique is referred to as a probe hole technique. Single crystal planes will be used during the study.

Feld emission has its applications in both surface science and the technological field. Scanning electron microscope make use of routine field emission sources. The same applies for an e-beam. This is because field emission has a small optical size. A variety of techniques can be used when fabricating high-density two-dimensional array emitters. This leads to the production of emitters that can be used in panel displays. The emitters can also be used in electron tube devices.

Fluorescence

Fluorescence is referred to as the emission of light by a material that has absorbed electromagnetic radiation. Gas, liquids, and solid chemicals experience a type of luminesce referred to as fluorescence. Emitted light has relatively long wavelengths meaning that the photons are a lower energy compared to the absorbed radiation. Fluorescent materials are those that glow when exposed to radiation and the glow stops when the supply of radiation is stopped. There are three main events that govern the fluorescence process. The three events take place at different timescales identified by the order of magnitude. The first event involves the excitation of molecules by incoming photons. This event occurs in femtoseconds. The second event involves the vibrational relaxation of electrons in the excited state to a lower energy level. The event takes place in picoseconds. The final event involves the emission of photons with longer wavelengths which returns molecules to the ground state. This event takes a longer duration of time known as nanoseconds (Baruah and Dutta, 2009). The fluorescence process is a unique manifestation of the interaction process exhibited between matter and light, forming the foundation for expansive fields of time-resolved and steady-state microscopy and spectroscopy. Fluorescence is a growing method useful in cell biology and genetics. It is used with conjugated polycyclic aromatic molecules existing at either of the energy levels, each linked to a certain arrangement of electronic molecular orbits. Distribution of negative charges and the general molecular geometry is determined by the electronic state of the molecule. There are various electronic states where molecules could exist. The electronic state of a molecule is determined by the symmetry of different electron spin states and the total electron energy. The electronic states of electrons can further be categorized into a number of rotational and vibrational energy levels linked to the bonding orbitals and atomic nuclei. An electronic singlet where all electrons are had opposite spins is referred to as the ground state. Few molecules at room temperature have enough internal energy to exist in any state beyond the lowest vibrational level of the ground state. For this reason, it is said that the excitation process originated from this energy level. There are certain groups of molecules able to undergo electronic transitions leading to fluorescence. These molecules are known as dyes, fluorochromes, and fluorescent probes. Fluorochromes can be put together to form relatively large macromolecules such as protein, enzyme, lipid, and nucleic acid through covalent bonds and absorption referred to as fluorophores. Fluorophores can further be categorized into extrinsic and intrinsic. Extrinsic fluorophores are those that can be added to specimen resulting in fluorescence with certain spectral properties. They include modified biochemical and synthetic dyes. Intrinsic fluorophores are naturally occurring (Bohr, 2002). They include green fluorescent protein, porphyrins, neurotransmitters, and aromatic acids. Fluorescence emissions are affected by a number of environmental factors. They include the concentration of the fluorescent species, pH, temperature, organic, and inorganic compounds and dictated solvent polarity. Effects of the factors vary from one fluorophore to another. There are certain factors that are heavily influenced by environmental variables which include quantum yields, emission, and absorption spectra. Interactions occurring within the local environment during the excited state results in a relatively high degree of sensitivity in fluorescence. While in the excited star, a fluorophore can be considered to be a different molecule. This is means that it will portray a different set of properties with regards to the interaction in the environment (Figure 13).

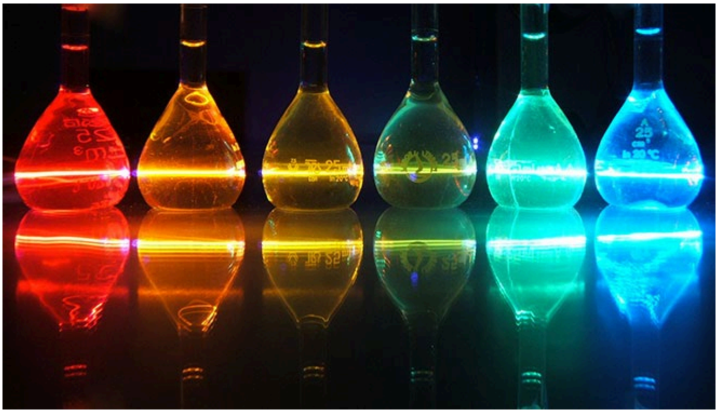


Figure 13. Fluorescence is an electromagnetic wavelength that creates color.

Source: https://promocell.com/cell-culture-basics/fluorescent-labeling/.

Fluorescence Spectroscopy

Fluorescence spectroscopy is built on fluorescence. It is a method of analyzing fluorescence from a molecule by looking into their fluorescent properties. Fluorescence is a phenomenon describing a type of luminescence brought about by molecules being excited by photons. This results in the molecule moving to an electric excited state. Fluorescence spectroscopy makes use of a beam of light which excites the electrons in the molecule of a given compound. This results in the emission of light. Light used in this case is directed to a filter and a detector for identification and measurement of the molecule. The same case applies to the changes in the molecule. When molecules get excited by a constant source of light and emit fluorescence, it is referred to as a steady-state fluorescence spectrum. They emit photons that can be detected as a function of wavelength. If the excitation wavelength of the molecule is fixed a fluorescence emission spectrum is achieved. In this case, the emission wavelength can be scanned to generate a plot of intensity against emission wavelength.

When the excitation monochromator wavelength is scanned and the emission wavelength established as fixed then a fluorescent excitation spectrum has been achieved. The generated spectrum is very useful in providing information on the wavelengths in which a same is able to absorb energy. The same applied to the amount of emission it can give off at the single emission wavelength selected for observation. It is therefore to analogous to an absorbance spectrum. However, it is a very sensitive technique with regards to limits of molecular specificity and detection. Fluorescence spectroscopy looks into the excitation spectra of molecules (Bowman and Hodge, 2007). The spectra are specific to a certain species as opposed to an absorbance spectrum. The absorbance spectrum measures all-absorbing species in a substance. For certain fluorophore, the excitation and emission Spectra are mirror images of each other. The absorbance and excitation spectrum occur at low energies, while the emission spectrum occurs at higher wavelengths. Under spectroscopy, there are two main types of spectra which are excitation and emission. They are used to check how a sample change. The peak wavelength or spectral intensity varies with variants like interactions with other molecules close to it, concentration, and temperature. Certain fluorophores are sensitive to solvent environmental properties like polarity. Fluorescence spectroscopy involves the use of fluorescent molecules. These molecules come in different sizes and shapes. Intrinsic fluorescent materials include amino acid residues such as tyrosine, phenylalanine, and tryptophan. Fluorescence spectroscopy has been applied in different fields like chemical research, medical, and biomedical fields. The technique is used in analyzing organic compounds. In some areas, it is said to be used in the medical field in differentiating between a benign and a malignant skin tumor. Atomic fluorescent spectroscopy methods are utilized in other forms of measurement and analysis of compounds present in water or air. CVAFS are used in the detection of certain metals such as mercury. The technique can also be used in redirecting photons. It can also use microfluorimetry in adapting it to a microscopic level.

Fluorescent Probe

Fluorescent probes are described as molecules with the ability to absorb light of a given wavelength and emit light with a different wavelength. The resultant wavelength is usually longer than the original and is used in studying biological samples. The process of producing wavelengths is referred to as fluorescence. The used molecules are referred to as fluorophores. They can be attached to target molecules. They can also act as marker during analysis with fluorescence microscopy. Each of the molecules have their own unique characteristics. These characteristics are useful in determining the kind of fluorophore to be used for an experimental system or application. Some of the molecules are naturally occurring. In most cases, they are proteins and small in size. These kinds of molecules are referred to as intrinsic fluorescence. They include the green fluorescent protein. Extrinsic fluorophore can be used in labeling small molecules, lipids, nucleic acids and proteins. An example of an extrinsic fluorophore is a fluorescent dye. It has a quantum dot; it is a protein and a small molecule. Among the extensive uses of fluorophores is biological research. The demand of these molecules continues to grow due to their quantitative abilities, sensitivity, and versatility (Bhattacharyya et al., 2009). Fluorescent probes are mostly used in detecting protein location and activation. It is also used in identifying the formation of complex proteins and conformational modifications. The probes are also used in monitoring biological processes in vivo. Representative images are generated using immunofluorescence techniques. Among the significant innovations made in science and physics to be specific is the discovery and subsequent development of fluorescent probes. Its discovery allows the interpretation of a number of biological phenomena. In the biomedical field, fluorescent probes are used in high-throughput screening, clinical diagnostics, and pharmaceutical research. Currently, there is a sufficient number of existing probes. However, efforts are underway to produce new versions acceptable under novel chemistry. This will address challenges of currently existing approaches. Multivalent probes are used in the study of glucose transport as outlined in patent application. The different varieties of fluorescent probes discovered over the years allow them to be patentable in various industries. Among the application of fluorescent probes is that metal ion sensors in cellular systems during live-cell imaging and protein tagging in medical diagnostics. Fluorescent probes can be prepared through extensive methods. These methods are covered under parents. There is a patent that deals with synthetic bioprobes. Peptide template fluorescent nanoclusters are used to prepare this kind of probes. Nanoclusters have small sizes making them useful in imaging and intracellular probing (Xia, 2008). Compared to nanoparticles, nanoclusters are of much smaller sizes. Certain quenched fluorescent probes exhibit fluorescence through biochemical processes. One of the patents covers this kind of fluorescence. Fluorescent probes can be created in such a way that under certain conditions, they have intramolecular quenching. As the quencher cleaves from the probe, it becomes fluorescent. Such kinds of probes are mostly used in vivo imaging.

Fuel Cell

A fuel cell is a device involved in the use of chemical reactions in generating electricity. Usually, the fuel cells are made up of two electrodes, each named according to the charge. The positive electrode is called the anode, while the negatively charged electrode is called the cathode. For electricity to be produced, both electrodes have to be involved in the reactions. An electrolyte is an essential component in the fuel cell. The electrolyte carries the electrically charged particles and transfers them from one electrode to another. It also acts as a catalyst as it speeds up reactions at the electrodes. Fuel cells need oxygen. One of the most common fuels is hydrogen. A major advantage of fuel cells is that they can be involved in the generation of electricity with little pollution. Both oxygen and hydrogen are used in electricity generation. They combine resulting in the formation of water. This is a harmless by product. Fuel cells generate direct current. A single cell produces a small amount of electricity. Usually, several fuel cells are put together to form a stack. The stack follows the same principle as the cell. Fuel cells are made with the aim of generating electric current which is supplied outside the cell (Weiss et al., 2020). The generated current is used in powering electric motors and illuminating light bulbs. Behavioral tendencies of electrical current require the current generated to return back into the fuel cell. This means that the electric circuit has to be complete. To better understand how fuel cells work, one needs to know and understand all the chemical reactions that take place in a fuel cell. There are different kinds of fuel cells, each having its own mode of operation. The general working of fuel cells involves hydrogen atoms entering a fuel cell at the anode. A chemical reaction occurs in the anode which strips hydrogen of their charges. This results in hydrogen atoms being ionized as they carry a positive electrical charge. Current flowing through the wires is supplied by negatively charged electrons. In some instances, industries require alternating current. In such a case, the DC current from the fuel cell is routed to a conversion device. This device is commonly referred to as an inverter. Oxygen enters the cell through the cathode where it combines with electrons finding their way into the electric circuit. They also combine with hydrogen ions that have moved from the anode (West and Halas, 2000). In certain fuel cells, oxygen takes up oxygen and finds its way through the electrolyte to the anode. There, there are hydrogen ions. They combine. Electrolytes play a vital role in fuel cells. They allow only the suitable ions to pass between the cathode and anode. A chemical reaction can be disrupted or hindered if free electron were allowed to flow through the circuit. In the fuel cell, oxygen and hydrogen combine to form water. This is reaction can take place in the anode or cathode. The generated water is emptied from the cell. A fuel cell can work for a long duration of time provides that both oxygen and hydrogen are supplied to the cell. Another advantage of fuel cells is that electricity is produced through chemical reactions rather than combustion.

This means that they do not subject to thermodynamic laws which may prove problematic in a conventional power plant. This also means that fuel cells are a more efficient source of energy. It also allows harnessing of waste heat from certain cells. This increases the efficiency of the system (Figure 14).

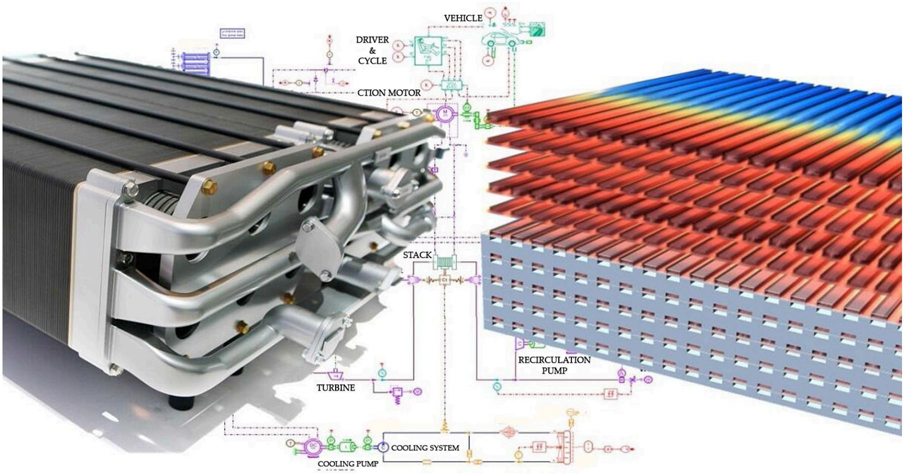


Figure 14. Fuel cell design using an assimilated simulation approach.

Source: https://www.plm.automation.siemens.com/global/ru/webinar/simulation-for-fuel-cell-design/70845.

Fullerene

There different allotropes of carbon fullerene bring one of them. A fullerene is a carbon allotrope made up of carbon atoms joined together by dingle and double bond resulting in the formation of a wholly or partially closed mesh consisting of fused rings of 5–7 atoms. This carbon molecule may take the form of a hollow sphere, tube, and ellipsoid, among other shapes. Sizes of the molecules also vary. A flat mesh of regular hexagonal rings commonly referred to as graphene is considered an extreme member of the fullerene family. An empirical formula is used in denoting fullerenes with closed mesh topography. The empirical formula is written as Cn where n represents the number of carbon atoms. There are certain special cases characterized the unique value of n. Fullerenes got their name from the Buckminsterfullerene. This is the most commonly known member of the fullerene family. Its name was changed to the Buckminster Fuller. For closed fullerene with the n value being 60 is informally known as buckyballs as they reassemble a basic soccer ball. Bucky onions is the name given to closely nested fullerenes while bucky-tubed or CNTs used to refer to cylindrical fullerenes. A pure form of fullerene is referred to as a fullerite. By discovering fullerenes, chemists were able to discover other unknown allotropes of carbon. By closely researching more about carbon allotropes, chemists got more knowledge on the technological applications of carbon allotropes. This resulted in fullerenes being used in nanotechnology and electronics.

Bonding nature is a key property of fullerene. All the carbon atoms connect to three neighbors. This is a deviation from the normal four bonds. This allows further description of bonds into a combination of both single and double covalent bonds. C60 has been hybridized. This bonding state is well analyzed by X-ray photoelectron spectroscopy, UR spectroscopy and Raman spectroscopy (Thompson, 2011). Another property of fullerenes is the encapsulation also referred to as endohedral fullerenes. They are made up of small molecules or ions put together in a cage of atoms. Fullerenes have a broad area of application, more so in the biomedical field. It is used in drug and gene delivery, photodynamic therapy, X-ray imaging contrast and designing high-performance MRI contrast agents. With regards to medicinal use, fullerene was found to be useful in binding certain antibiotics of a given structure on to a resistant bacterium. It could be used in targeting specific cancer cells. By using fullerenes, chemists are looking into ways in which other modes of cancer treatment can be created and incorporate the use of technology.

G

Genome

A genome is an organism containing a set of genetic instructions. Genomes are fitted with information required to build organisms and enable them to grow and develop. The human body is made up of several cells. Each cell contains its own set of instructions. These instructions allow the body to properly function as a system. The set of instructions governing our bodies is referred to as the genome. The genome contains DNA. Every cell in the body carries DNA. Cells carry instructions to suit the functions of the part they serve. For instance, cells in the liver and skin have a similar set of instructions. The DNA makes up instructions fitted in our genomes. In the DNA, there are certain unique chemical codes that direct the growth, health, and development of the human body (Sozer and Kokini, 2009). The type of code found in the human body is determined by the order of four nucleotide bases which constitute the thymine, guanine, cytosine, adenine, and DNA. DNA is said to have a double helix shape as its strands are twisted in nature. Individuals DNA strands are coiled up forming structures known as chromosomes. The chromosomes are found in the nucleus of the cell. DNA sections are read together within the chromosomes to form genes. Human characteristics such as height and eye color are determined by genes. Genomes are unique in every human being. 3.2 billion bases of DNA combine to form the human. This is may not apply for other organisms as their genomes are of different sizes. Without a genome, an organism cannot survive.

Genetic Sequencing

Genetic sequencing is the process of finding out the order of bases and DNA nucleotides in a genome constitute an organism's DNA. There are over 3 billion genetic letters that make up the human genome. Over the years, DNA sequence has developed from a small-scale practice to a large scale. By carrying out this practice on a large scale, it gives room for highly ambitious projects including sequencing of whole genomes. This process involves the use of highly technological devices. These devices have been made such that they are able to "read" a sequence of DNA bases. Genome sequencing is usually compared to decoding though the sequence of the gene is entirely a code. A genome sequence reveals more information about a genome. It basically contains a long string of letters written in a unique language. The language is often at times described as mysterious. The genome of an organism entails more than just the sequence. This is because often at times letter sequence to not constitute its meaning. The grammar in the language as well as the words made up by the letters will determine whether a sentence makes sense. Genome sequencing is different from normal sentences in that the letters are not punctuated, capitalized with no beaks between letters, words, sentences, or paragraphs. It is quite difficult to make sense of letters constituting a genome sequence. Different techniques are used in genome sequencing. The same applies to technology.

Gas-Phase Reactions

There are different kinds of reactions in chemistry among them being the gas-phase reactions. They are considered to be the simplest form of chemical reactions to occur. Gas-phase reactions also take place in a single step. A good example of a gas-phase reaction is the transformation of a chlorine atom for CINO to form nitrogen gas and CINO. For a chemical reaction to be properly written down, one needs to have knowledge of Lewis structures for all elements involved in the chemical reaction. For instance, NO_2 and NO have odd number of electrons (Smith et al., 2013). Both components can combine with a neutral chlorine atom resulting in the formation of a molecule in which all electrons are paired. A graph can be plotted to show the reaction showing how the $CINO_2$ disappears while the NO_2 appears in the course of the reaction. The graph also demonstrates the rate of reaction. The rate of reaction is the rate at which reactants change into products. Equations of states are the mathematical equations used to describe the rate of chemical reaction. In this case the equation is described by the rate law for the reaction; which is as follows: $k(CINO_2)(NO)$

From the law, we learn that the rate at which CINO 2 and NO are converted to NO_2 and CINO is proportional to the product of the concentration of the two compounds. At the start of the reaction, the rate was fast. This is because the concentration of the reactants was very high, but as the reaction continued, products were formed and the concentration of the reactants reduced. This leads to the decrease in the rate of the reaction. Normally, one would expect that once the reactants are fully consumed and converted into products is when the reaction would stop. In a practice situation, this would not be the case. The rate of concentration of CINO 2 reduces by a factor or two in less than a second. At the end of the reaction process, some residues of NO and $CINO_2$ will be noted in the reaction container. A graph can also be plotted on the reaction in the kinetic region and equilibrium region. The kinetic region can be defined as the period in which the concentration of the components in the reactions are constantly varying. The equilibrium region is defined as the period after which the reaction process seems to stop. In this period, there is no change in the concentration of components in the reaction.

The reaction between $CINO_2$ and NO appears to stop before all the reactants are used in the reaction process is explained using a model of chemical reactions known as the collision theory. In the model, it is assumed that the NO and $CINO_2$ molecules should collide for a chlorine atom to be transferred from one molecule to another. It works on the assumption that the rate of the reaction is proportional to the concentration of reactants. The number of collisions between the reactants is dependent on the concentration. As the reactants are consumed during the reaction, the number of collisions per second between the molecules reduce as the reaction slows down. From the reaction we define equilibrium as the state of a system whose rate of forward and reverse reactions are equal. It can also be defined as a system in which no apparent changes are noted in the concentration of both products and reactants in the reaction (Seil and Webster, 2012).

Gene Expression

Gene expression is referred to as the process in which instructions in the DNA are converted into functional products like proteins. The information stored in the DNA are converted into instructions. This plays a vital role in the making of proteins or other molecules. Gene expression is a crucial process and for this reason it is tightly regulated. It enables cell to respond to changes in the environment. It can also play the role of a switch. It can switch on or off the process in which proteins are made. It can also act as a volume control allowing the decrease or increase in the amount of proteins being made. The protein making process involves two major steps, including translation and transcription. Transcription process involves the DNA in genes being copied to produce an RNA transcript. This transcript is called the messenger RNA (mRNA). The transcription process is carried by an enzyme known as the RNA polymerase. It makes use of all the available bases from the nucleus of the cell, allowing the formation of the RNA. The RNA is a chemical having the same structural characteristics with DNA. The only difference is that the RNA had a single strand of based. Also, its base is made of uracil rather than thymine.

In the case of translation, the process occurs after the mRNA had carried the transcribed message from the DNS to the cell. In the cell, the messages are taken to the protein-making factories. They are called ribosomes. The transfer RNA (tRNA) is involved in reading of the message carried by the mRNA. tRNA is called a carrier molecule. Three letters are read at a time in the mRNA. The letters are referred to as codon. The codon specifies a particular amino acid. A glycine is the name given to the three bases GGU code in an amino acid. There are 64 potential combinations of codons though there are only 20 amino acids. More than one codon can code for two or more amino acids. Both the GGU and GGC code for glycine. Every amino acid is attached to its own tRNA molecule. After the reading of the mRNA sequence, each tRNA molecule takes its amino acid to the ribosome. It temporarily binds to the corresponding codon on the mRNA molecule. When the tRNA is bound, its amino acid is released and the adjacent amino acids join together into a long chain. This chain is called a polypeptide. The process goes on until a protein is formed. The active function in a cell is carried out in proteins.

Gene Sequencing

Gene sequencing is at times referred to as DNA sequencing. It is a method used in laboratories in determining and extracting sequence of bases within a DNA molecule. The bases referred to in this case are the T, G, C, and A. Information is usually stored in the cell. The DNA bases sequence is involved in carrying the information needed in the cell. This information helps the cell perform certain duties such as the assembling RNA molecules and proteins. For scientists, gene sequence information is vital in giving more information on the functions of genes. With gene sequencing, various technologies have been innovated to help in the process. One of the technologies is the DNA sequencing which is cheaper and takes a shorter duration of time. It was initially created as a human genome project. A good example of how gene sequencing is used by scientists is when the use the DNA sequencing information is used in determining the stretches of DNA that contain genes and which stretches carry the regulatory instructions which turn off or on (Sawhney et al., 2008). Also, scientist use this information in identifying changes in the gene that can lead to diseases. Base pairs in DNA are formed when the four chemical bases bond with their partner. This very common in the DNA double helix. Bonding is as follows, Adenine pairs with thymine while cytosine pairs with guanine. The bond formed through pairing forms the foundation for the mechanism through which DNA molecules are copied as cell divide. The pairing also highlights the method through which several DNA sequencing experiments are conducted. About 3 billion base pairs ate found in the human genome. These base pairs spell out the instructions used in making and maintaining a human. The Human Genome Project was completed years back. It formed the foundation for gene sequencing. The completion of the project has created room for other projects to be developed. The current technological improvements are such that they are highly automotive working at a very high speed. They are also relatively cheaper. This has allowed individual genes to be sequenced routinely while other laboratories have been able to sequence over 100,000 billion bases annually. This allows gene to be sequenced at a good price. Other gene sequencing technologies have been developed with the support from various institutes among them is the National Human Genome Research Institute. The sequencing makes use of the Genome Technology Program as well as the Advanced DNA Sequencing Technology awards. Among the objectives of the institute is to promote new technologies seeing the reduction of the cost of sequencing of a human genome while ensuring high quality genome sequences are produced at a cheaper price (Figure 15).

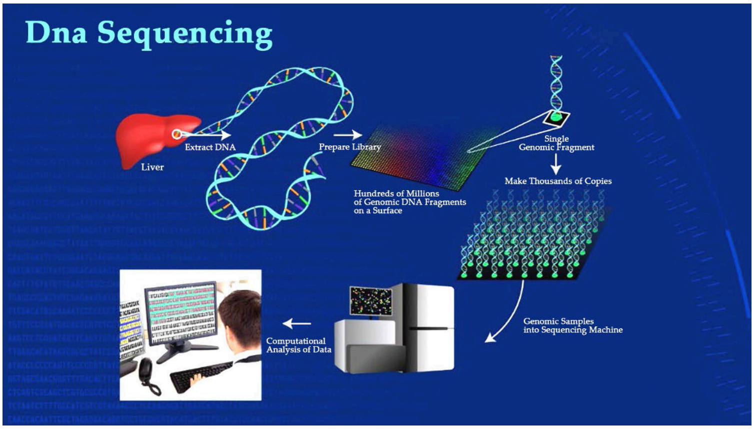

Dna Sequencing
Liver
Extract DNA
Prepare Library
Hundreds of Millions of Genomic DNA Fragments on a Surface
Single Genomic Fragment
Make Thousands of Copies
Genomic Samples into Sequencing Machine
Computational Analysis of Data

Figure 15. DNA sequencing in a lab.

Source: https://www.genome.gov/about-genomics/fact-sheets/DNA-Sequencng-Fact-Sheet.

Genomics

Genomic is a field in biology that places much focus on the mapping, evolution, function, structure, and editing of genomes. It is considered an interdisciplinary biological field. A genome is defined as the set of DNA found in an organism's body. A genome is composed of genes and the hierarchical, three-dimensional structural configuration. Genomic and genetics are very different. While genetics refers to the study of single genes and their involvement in inheritance, genomics refers to the process of collective characterization and quantification on the genes of an organism. In genomics, the interrelations that occur within cells and influence the organism. Genes are usually involved in protein production. They are usually assisted by mRNA and enzymes. Produced proteins are in turn involved in the making of body structures like tissues and organs. They are also involved in chemical reaction and transportation of signals within cells. Genomics also incorporates the analysis and sequencing of genomes by using high throughput DNA sequencing and bioinformatics in assembling and analyzing functions and structure of whole genomes. Discovery-based research has been championed for by advancements in genomics (Safari and Zarnegar, 2014). The advancements have also been used in systems biology to facilitate the understanding of very complex biological systems like the brain. Genomics as an interdisciplinary involves the study of intragenomic phenomena like epistasis. This phenomenon occurs within the genome and involves effect of on gene on another. It is also involved in the study of pleiotropy which involves a gene influencing more than one human trait, heterosis affecting hybrid vigor and other interactions within genomes. Genomic as an interdisciplinary has been used in a variety of areas hence its extensive applications in various fields such as social sciences, anthropology, biotechnology, and medicine. In the medical field, genomic technology is used by biomedical researchers and clinicians in increasing the amount of genomic data. They collect data from a significantly large population. In some cases, genomic is combined with informatics approaches able to integrate various kinds of data more do with genomic disease research. By so doing, researchers are able to understand the genetic bases of diseases and drug response. Various tools have been developed to help in interpreting the human genome.

Green Chemistry

Green chemistry refers to the designing of chemical products and processes in a manner that ensures a reduction or elimination of hazardous substances. Various organizations are working towards an environment free from hazardous substances. The EPA is one among the various organizations working towards an environment free from hazardous substances. They have made several efforts to fasten the adoption of green chemistry. According to the EPA, green chemistry is a revolutionary and diverse discipline which when adopted could result in innovation, environmental benefits, and an improved economy. Green chemistry makes use of 12 principles. They better explain the concept championed by green chemistry.

They include waste prevention which involves scientists designing chemical synthesis to prevent waste. This means that waste should be treated or well managed. Another principle is the maximization of atom economy where design synthesis ensures that the resulting products contains the maximum proportion of starting materials leaving few or no atoms being wasted. The third principle involves the design of less hazardous chemical synthesis. The design synthesis should make use of substances with little or no toxicity to the environment. The same applies to the products bring generated. Principle four looks into the design of safer products and chemicals. The products and chemicals should be highly effective with little or no toxicity. Principle five looks into the use of safer solvents and reaction conditions. This places much emphasis on the use of very safe chemicals while avoiding the use of auxiliary chemicals, separation agents and solvents. Principle six focused on the increased use of energy efficiency wherebychemical reactions are done at room pressure and temperature where applicable. The next principle champions for the use of renewable feedstocks (Ravichandran, 2010). In this case feedstocks also known as stating materials, renewable in nature, are used. Renewable feedstocks are normally sourced from agricultural products or wastes from other processes. Some feedstocks are depletable. They include fossil fuels and mining operations. The next principle discourages the use of chemical derivatives. This means that protecting or blocking groups or those with temporary modifications should be avoided. This is because they generate waste and make use of additional reagents. The other principle champions the use of catalysts rather than stoichiometric reagents. Catalytic reactions tend to have a smaller amount of waste. This is because catalysts are very effective in small amounts allowing them to conduct a single reaction several times. For this reason, they are preferred compared to stoichiometric reagents. Stoichiometric reagents are needed in large amounts and can conduct a reaction once.

There are several advantages of green chemistry to human health and the environment. The major advantage of green chemistry to the environment is that the environment becomes less polluted and can resume its initially healthy state. On human health, some of the advantages include it leading to cleaner air as the amount of hazardous chemicals being released in the air is less. This reduces the incidence of diseases caused by air pollution. It also ensures clean water as reduced amounts of hazardous chemicals are released in to water, increasing the amount of drinkable and recreational water. It also increases worker safety in chemical in industries and workers are exposed to less amounts of toxic materials. Under green chemistry, workers are required to wear protective equipment. It also reduces the likelihood of accidents occurring.

H

Heterogeneous Catalysis

The heterogeneous catalysis is a form of catalysis whereby the physical state of a catalyst is different from the reactants in a chemical reaction. Catalysis is considered an essential chemical reaction as it fastens the rate of chemical reaction. Catalysts are substances added in chemical reactions so as to speed up the rate of the reaction. Catalysis can take two forms determined by the type of catalysts involved. Catalysis is classified into homogeneous and heterogeneous catalysis. Homogeneous catalysis is one in which both the catalyst and reactants are in the same physical state. This means that if the catalyst is a liquid the reactant is also a liquid (Presting and König, 2003). It is best exemplified by acid catalysis and organo-catalysis. For the heterogeneous catalysis, the reactants and catalyst are in different physical states. The reactant may be a solid while the catalyst is liquid form. The most common form of the heterogeneous catalysis is when the catalyst is solid in nature while the reactant is a gas. In such a reaction, there is a cycle of molecular desorption, reaction, and adsorption taking place on the surface of the catalyst. The rate of reaction is influenced by heat transfer, mass transfer and thermodynamics. Heterogeneous catalyst plays a vital role in that they enable quick large-scale production. It also allows selective product formation.

High Throughput Screening

High throughput screening is defined as the use of automated equipment in the rapid testing of large samples for biological activity at the molecular, pathway, cellular or organism level. It is considered an experimental process involving small molecule compounds with established structures getting screened in parallel. Screening is not fixed to small-molecule compounds. It can also be done on other substances, including antibodies, oligonucleotides, natural product extract and chemical mixtures. The main goal of HTS is to screen more than 100,000 samples in a day, some processes are important. They include automated data processing, robotic-assisted sample handling, automation-compatible assay design and relatively sampling. The HTS method is usually used in biotechnology and pharmaceutical companies in identifying compounds referred to as hits in biological and pharmacological activity. They are used as starting points n medicinal chemical optimization during drug discovery and development as well as pharmacological probe. A common HTS assay is done in microtiter plates in certain formats. The traditional HTS allowed the testing of one compound in a compound library while at a single concentration (Porter et al., 2008). The high throughput screening is a quantitative method used in testing compounds at multiple concentrations while using an HTS platform. As each compound is tested, concentration-response curves can be generated immediately after the screen is performed. Quantitative HTS has over the years become more popular more so in toxicology as it allows for proper characterizing of the biological effects of chemicals. It also reduces the rate of false negatives and false positives. Various technologies are used to improve the efficiency of HTS. Compounds are said to exhibit unique distribution of compounds across one or more plates. These distributions can be employed in increasing the number of assays pet plate. It also reduces the variance of assay results. In some cases, it can do both. There is a simplifying assumption used when using this method. The assumption is that any N compound will not interact with each other.

Homogeneous Catalysis

Homogeneous catalysis is a technology that is continuously being improved to deal with challenges presented by previous technologies. There are several advantages of the homogeneous catalysis. They include the fact that homogeneous catalyst is more selective when compared to heterogeneous catalysts. During exothermic processes the homogeneous catalysts introduce heat into the solvent. Finally homogeneous catalysts are easy to characterize precisely. This means that their reaction mechanisms are amenable to rational modifications. There are also disadvantages of using homogeneous catalysis. Among the challenges is the fact that it is quite a challenge to separate homogeneous catalysts from reaction products (Patil et al., 2008). There are cases where high activity catalysts are involved in a reaction, and in this case, the catalyst is not removed from the products. Specials cases where separation occurs is when organic products are suitably volatile. There is a challenge of homogeneous catalysts with regards to thermal stability whereby when compared to heterogeneous catalysts, the homogeneous catalyst exhibit limitations with thermal stability. There are different examples of homogeneous catalysis among them is the acidic catalyst. In this catalyst, the proton is considered to be the pervasive homogeneous catalyst. This is because the common solvent is water. Through the self-ionization of water, protons are formed by water (Figure 16). Acid catalysts can be used in catalyzing the hydrolysis of water as illustrated by the equation below:

$$CH_3CO_2CH_3 + H_2O \rightleftharpoons CH_3CO_2H + CH_3OH$$

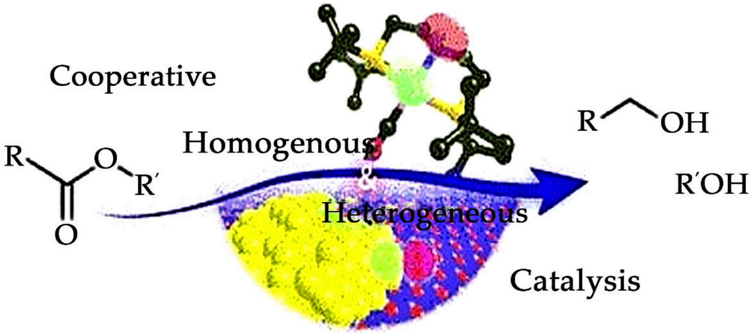


Figure 16. Comparison of homogeneous and heterogeneous catalysis.

Source: https://qsstudy.com/chemistry/differences-homogeneous-catalysis-heterogeneous-catalysis.

At a pH of 7 (neutral) most ester solutions do not hydrolyze at experimental rates. Another example us the transition metal-catalysis. In this case, hydrogenations are the prominent class of reductive transformations. In such reactions, hydrogen is added to unsaturated substrates. The transfer of hydrogen from one substrate to another is referred to as transfer hydrogenation. The substrate transferring hydrogen is referred to as the hydrogen donor whole the substrate receiving hydrogen is referred to as the acceptor. Other related reactions involve HX additions. In such reactions, hydrocyanation and hydrosilylation equate to X. While heterogeneous catalysts are conducted in several large-scale hydrogenations involving production of benzene-to-cyclohexane, benzene, ammonia, and margarine, homogeneous catalysts are often used in fine chemical synthesis.

Carbonylations is another homogeneous catalysis. In this case H and C (O)H are added to a double bond. A prominent form of carbonylation is hydroformylation. Cobalt-containing complexes and soluble rhodium are exclusively conducted during the process. Conversion of alcohol to carboxylic acid is referred to as related carbonylation. Acetic acid is formed when CO and MeOH react in the presence of a homogeneous catalysts. This kind of reaction mostly occurs in the Monsanto process and cativa processes. Other related reactions include hydroestetifications and hydrocarboxylation. Polymerization and metathesis are another form of homogeneous catalysis (Pathakoti et al., 2018). The Zeigler-Natta catalyst is involved in the reaction between propylene and ethylene. Products of the reaction include polypropylene and polythene collectively known as polyolefins. Although heterogeneous catalysts are mostly used in such reactions, reactions producing stereospecific polymers use soluble catalysts. Homogeneous catalysts are highly valuable in fine chemical synthesis, while heterogeneous catalysis is preferred in other industries. Oxidation is another example of homogeneous catalysis. These reactions involve the use of homogeneous catalysts in oxidation reactions. Oxygen and ethene are used in the production of acetaldehyde. This process is called the Wacker process. Oxidation reaction may utilize non-organometallic complexes. One area of application is the production of terephthalic acid from xylene. Metal complexes also dehydroxylate and epoxidize alkenes.

Hydrogen Bonding

Hydrogen bonding is a unique type of dipole-dipole attraction exhibited between molecules of the same or different type. For this reason, hydrogen bonding is not a covalent bond to hydrogen atoms. This kind of bonding involves an electropositive ion being attracted to an electronegative ion. For instance, a hydrogen atom exhibits an electropositive charge and an attractive force between a hydrogen atom and an electronegative molecule like oxygen, nitrogen or fluorine causes the creation of a covalent bond between the two. For every mole of hydrogen bond, strengths vary from 4–59 KJ. Molecules with fluorine-Hydrogen, oxygen-hydrogen or nitrogen-hydrogen bonds exhibit a relatively large variation in electronegativity between fluorine, oxygen or nitrogen and hydrogen. This results in the creation of a highly polar covalent bond. The hydrogen bond can also be defined as an electrostatic dipole-dipole interaction. Hydrogen bonding bears some features of covalent bonding. They include the fact that they produce short interatomic distances. The interatomic distances are said to be shorter than the sum of Van der Waals radii. The bonds are also directional and strong. The bonding also entails a controlled number of interaction partners at times interpreted as a valence type. Every molecule has its unique electronegativity values (Nikalje, 2015). For instance, the electronegativity values for hydrogen are 2.1 while that of oxygen is 3.5. The electronegativity difference causes the hydrogen atom to bear a large partial positive charge while atoms of fluorine, oxygen, and nitrogen bear a large partial negative charge. This makes the hydrogen atom to be electrostatically attracted to the fluorine, oxygen, or nitrogen atom. For this reason, hydrogen bonding can be described as an interaction process when a hydrogen atom is found between a pair of other atoms with a high affinity for electrons. The negative charge in atoms of fluorine, oxygen, and nitrogen have an unshared electron pair. Water is an example of a liquid form through hydrogen bonding. Water is formed through extensive hydrogen bonding and has a relatively good range of temperature. In ionic compounds, water is considered a good solvent. This is because it easily dissociates to form hydrogen bonds with the solute. The manner in which hydrogen bonding between amino acids occurs in a linear protein molecule will determine the manner in which it folds up to a functional configuration. There are different consequences of hydrogen bonding. Hydrogen bonding explains why nitrosyl fluoride is a gas while water is a liquid. Though both have about the same shape, ONF has a higher molecular weight. This means that London dispersion forces cannot account for the difference in the compounds. Both water and ONF have the same dipole moment; therefore, dipole moments cannot account for the difference between the two compounds. However, water can form hydrogen bonds while ONF cannot. There are different applications of hydrogen bonding among them being drug production.

Hydrophilic Effect

To better understand the hydrophilic effect, the term hydrophile should be well understood. The term hydrophile is the name given to a molecule said to be water loving. They are said to be hydrophilic in nature. The opposite of hydrophilic is hydrophobic which is the term used to refer to a molecule which does not love water. Both terms (hydrophilic and hydrophobic) are used in describing the manner in which molecules react with water. Hydrophilic is the term used to refer to the extent to which a surface or molecule attracts water (Arora et al., 2014). Cellulose, sugar, starch, and salt are examples of hydrophilic substances. The hydrophilic effect influences the solubility of substances in water as well as the hydrophobicity-hydrophilicity in the immunogenicity of natural and synthetic polymers. The extent of hydrophilicity and hydrophobicity can be determined by contact angle measurements. Contact angles are used to obtain surface tension components which are then correlated with the extent of the immunogenicity of every substance. The aftermath shows that highly hydrophilic and highly hydrophobic polymers are not immunogenic. Immunogenicity in water is favored by moderate hydrophilicity and moderate hydrophobicity.

Moderate hydrophobicity as well as moderate hydrophilicity, and solubility in water favor immunogenicity (provided the molecular mass be at least 10,000 Da). For example, the solubilization of zein (a hydrophobic insoluble maize protein) prior to immunization causes zein to become immunogenic.

Hydrophobic Effect

The hydrophobic effect is a phenomenon whereby nonpolar molecules tend to self-associate in water rather than dissolving individually. When considered in general it may be misleading. This is because it focuses on the molecules themselves when actually the hydrogen bonding nature of water is the force behind it. The hydrophobic effect is used universally, more so among biochemists as they often speak of hydrophobic aide chains of a molecule being a shorthand when discussing the complexities of the water structures. The water structure is said to be affected by nonpolar constituents in biomolecules. A significant number of biomolecules are said to be amphipathic in that they have both water-hating and water loving parts. The water-hating parts are the hydrophobic part while the water loving parts are called the hydrophilic part. An example of a carboxylic acid functional group is the palmitic acid which is attached to a long hydrocarbon tail. Sodium palmitate found in sodium salt usually dissolves in water (Abolmaali et al., 2013). The hydrophobic effect causes the hydrocarbon tail to associate while the carboxylate group associates with water. A micelle is formed by a fatty acid. A micelle is a spherical droplet fitted with hydrocarbon chains inside it while the carboxylate group is found both on the inside and outside of the droplet. Among the constituents of soap is sodium palmitate. Examples of triglyceride esters include fats. They are made of three fatty acids esterified to a single glycerol molecule. The covalent bond between alcohol and carboxylic acid is referred to as an ester linkage. Fats are mobilized by soap micelles. This also mobilize other hydrophobic substances by dissolving them on the inside of the micelle. Fats are usually mobilized from the surface of objects being cleaned. This is because micelles are usually suspended in water. Compared to soaps, detergents are stronger cleaning agents. This can be attributed to the fact that in detergents, the hydrophilic components are highly charged compared to the fatty acid component in soap. A common component in hair shampoos is sodium dodecyl sulfate. It is considered to be a very powerful detergent and is usually used in experiments to disrupt the hydrophobic interactions which hold membranes together or influence the protein shape. A major element in the hydrophobic effect is the membrane association. A large part of biological membranes is the glycerol esters in fatty acids. These molecules are different from those found in fatty acids in that they contain two fatty acid side chains. There is a third component is the hydrophilic component. For this reason, they are amphipathic. The amphipathic molecule has both nonpolar and polar parts. As a phosphatidylcholine is suspended in water, through the hydrophobic effect molecules associate white the solvent being faced by the charged portion while the fatty acid side chains associates with each other. The molecules associate into a bilayer rather than making a micelle. This is done by a palmitate. The association into a bilayer result in the formation of a spherical vesicle defined both outside and inside. The spherical vesicle is termed as a liposome. Cell membranes and liposomes are similar though different in certain aspects. There are different and multiple types of lipids on biological membranes. Though they are bilayers, they are usually associated with the outside face of the cell while others are associated with the inside of the cell. Other than lipids, biological membranes also contain a large number of protein compounds. These membranes are said to be semi-permeable in nature and tend to exclude hydrophilic compounds such as ions, proteins, and carbohydrates while elements such as water, proteins, and oxygen freely pass through the membrane (Figure 17).

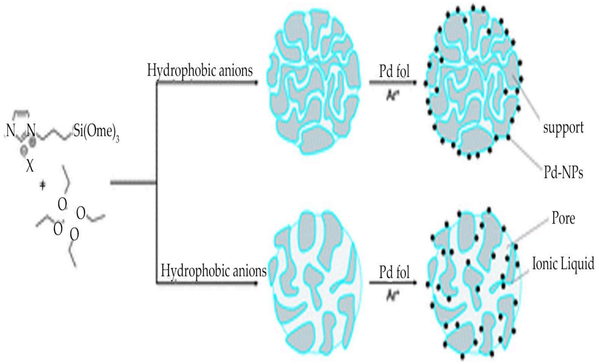


Figure 17. Hydrophobic impacts of nanoparticle hydrogenation catalysis.

Source: https://pubs.rsc.org/en/content/articlelanding/2014/cp/c4cp03063j.

The cause of the hydrophobic effect has not been well established. There are those who argue that hydrophobic interaction is as a result of an entropic effect that originates from disruptions between highly dynamic hydrogen bonds between liquid water molecules by nonpolar solutes. A nonpolar region and also a hydrocarbon chain of a large molecule do not possess the ability to form hydrogen bonds with water. If this kind of non-hydrogen bonding surface is introduced in water causes disruption of the hydrogen bonding network between water molecules (Baruah and Dutta, 2009). A tangential orientation is exhibited in hydrogen bonds on a surface. This is so as to reduce disruption of the hydrogen-bonded 3D network of water molecules. This results in structured water cages all over the nonpolar surface. There are various areas where the hydrophobic effect is applied. One of the areas is biochemistry. In this field, the hydrophobic effect is used in separating proteins while focusing on their hydrophobicity. To make the separation more effective, salt is added to increase the hydrophobic effect.

I

Immune Machines

We can argue that the growing repertoires of selected lymphocytes reflect a pattern of health—it is plausible to believe that healthy self-antigens are what lymphocytes see in utero and in the thymus. To put it another way, the adaptive immune system is first taught to detect a state of relative health. As a result, the similarity of a test antigen profile to the training set profile indicates that everything appears to be in order and that no damaging inflammation is required. A functional differentiation of a test antigen pattern to a healthy reference pattern, on the other hand, should elicit inflammatory responses from the immune system. Hypotheses work by encouraging experimentation, and the presence of a positive wellness profile necessitates experimental confirmation.

The immunological supervised machine learning process can be viewed as a wellness theory of adaptive immunity, with the immune process starting with a fundamental notion of a healthy body. The reference set of antigen receptors is tuned to a state of health; sickness is demonstrated by a large departure from a healthy pattern, no matter how modest (Bohr, 2002). The discovery of the genetic code in DNA has increased the number of diseases caused by mutant or aberrant DNA. Immunological machine learning suggests that immune health is more than just the absence of a disease; it is also a distinct body condition that must be learnt throughout the early stages of immune repertoire development (Figure 18).

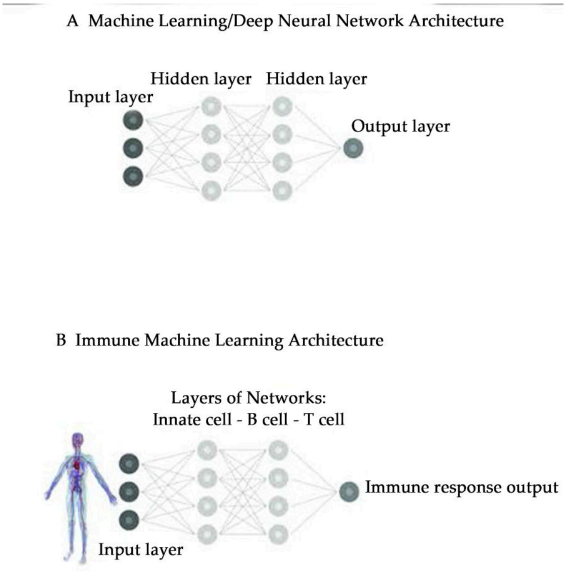

A Machine Learning/Deep Neural Network Architecture
Hidden layer
Hidden layer
Input layer
Output layer
B Immune Machine Learning Architecture
Layers of Networks:
Innate cell - B cell - T cell
Immune response output
Input layer

Figure 18. Immune cells collect input from the body, whether healthy or sick, and process it through interactions arranged as hidden layers of networks of Innate cells, B cells, and T cells.

Source: https://www.researchgate.net/figure/Supervised-Machine-learning-from-experience-A-represents-a-simplified-Architecture_fig3_330536923.

The approach identifies similar themes that are not obvious when looking at a narrower disease-specific view by employing machine learning and applying it to our unique diverse collection of single-sequencing data mixed with comprehensive clinical data. By recognizing minor variations in cell type and state-specific expression and distinguishing it from normal expression, the database of immune profiles supports biomarker development and insight production to assist answer crucial questions regarding the immune system.

Industrial Grade Nanotubes

The use of CNTs in diverse applications is determined by their dispersion in the corresponding matrix, which is in turn determined by the function used.

Depending on the oxidizing agent used, the functional group distribution on Carbon Nanotube surfaces is frequently a complicated mixture of groups. There are nine kinds of industrial quality multi-walled carbon nanotubes (MWCNT) with outer diameters of 10–30, 20–40, and 50–80 nm but different functionalities (carboxyl and hydroxyl) are investigated.

The industrial grade products contain more residual catalyst, amorphous carbon, and ash. On-demand, this product can be purchased by the metric ton. IGMWNTs are well suitable for applications that require the mechanical reinforcing qualities of CNTs but cannot afford the higher-grade goods. Paints, polymers, epoxies, and other materials can benefit from them (Bhattacharyya et al., 2009). Sold in kilograms and tons. Increased production volumes lower prices, allowing them to be used in commercial settings. Master-batches and composites are intermediary goods that take the guesswork out of incorporating CNTs into industrial products.

Intellectual Property (IP)

Patents are one type of intellectual property (IP); in the issue of access to medications, we are talking about patents. Patents are a tool used by governments to encourage innovation. Governments attempt to offer an incentive for R&D by giving a monopoly through a patent, which gives inventors an economic advantage. At the same time, technical growth benefits the general populace. Patent regimes all across the world are based on this trade-off. Governments must strike a balance between stimulating innovation on the one hand and ensuring that new items are broadly available on the other.

In underdeveloped nations, high levels of IP protection worsen rather than solve the problem of affordable medical availability. Patent protection for new drugs is extensive, which delays the onset of generic competition. Because generic competition is the only known strategy of lowering drug prices in a long-term manner, such high levels of IP protection are tremendously harmful to public clinical outcomes.

Patent extension rules allow corporations to request extensions of the 20-year patent period to compensate for patent offices and drug regulatory agencies’ administrative delays. (Delays like these are unavoidable in underdeveloped countries, where patent offices are chronically understaffed and dealing with an increasing quantity of patent applications.) By forbidding a country's drug regulatory authority from licensing a generic pharmaceutical based on the clinical trial data submitted by the originator firm, data exclusivity creates a monopoly distinct from patents (Bowman and Hodge, 2007).

Extending patent protection will not result in more R&D for medicines and vaccines that are desperately needed in underdeveloped countries. On the contrary, evidence suggests that high levels of IP protection impede access to medications. As a result, the USTR's proposed trade-off is untenable from the standpoint of public health and development.

Infrared Spectroscopy

Infrared spectroscopy (IR spectroscopy) is a type of spectroscopy that studies light in the infrared spectrum, which has a longer wavelength and lesser frequency than visible light. It includes a variety of approaches, the majority of which are based on absorption spectroscopy. It may be used to identify and analyze compounds, just like any other spectroscopic approach. A Fourier transform infrared (FTIR) spectrometer is a common laboratory device that employs this technology.

The idea that molecules absorb specific frequencies that are distinctive of their structure is used by infrared spectroscopy. These absorptions have resonance frequencies, which means that the frequency of the absorbed radiation is the same as the frequency of the vibrating bond or group. The shapes of the molecular potential energy surfaces, the masses of the atoms, and the accompanying vibronic coupling dictate the energies (Contreras et al., 2017).

Infrared spectroscopy is a simple and dependable technique that is frequently utilized in research and industry in both organic and inorganic chemistry. It is employed in quality assurance, dynamic measurements, and tracking applications like infrared gas analyzers' long-term unattended CO_2 concentration measurements in greenhouses and growth chambers. It is also employed in forensic analysis, both criminal and civil, to determine polymer degradation, for example. It can be used to determine a suspected drunk driver's blood alcohol content (Figure 19).

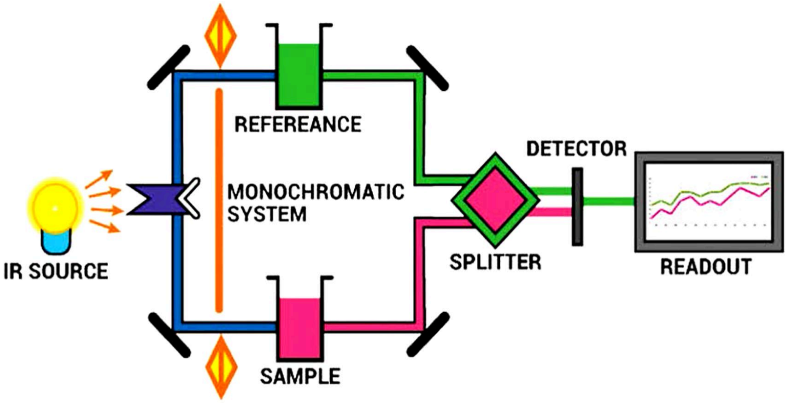


Figure 19. Because of its utility in detecting the structures of compounds and identifying them, it is one of the most common and commonly utilized spectroscopic techniques used mostly by inorganic and organic chemists.

Source: https://microbenotes.com/infrared-ir-spectroscopy/.

ATR, or attenuated total reflectance spectroscopy, is a handy means of studying solid samples without having to cut them. Samples are rubbed against the face of a single crystal in this method. Infrared radiation penetrates through the crystal and interacts with the sample only at the point where the two materials meet. Samples in solution may now be quantified precisely because of advances in computer filtration and manipulation technologies.

Infrared spectroscopy is also used in polymer manufacturing for determining the degree of polymerization. Measurements at a specified frequency throughout time are used to examine changes in the nature or quantity of a particular bond. Modern research tools can take infrared readings as frequently as 32 times per second within the spectrum of interest. This can be done while other approaches are used to make simultaneous measurements. This allows for faster and more accurate observations of chemical reactions and processes (Chauhan et al., 2012).

Ion Channel

Ion channels are proteins found in almost all live cells that allow charged ions from dissolved salts, such as calcium, potassium, sodium, and chloride ions, to flow through the otherwise impermeable lipid cell membrane. Ion channels are required for the operation of cells in the nervous system, heart, and skeletal muscle contraction, and pancreatic secretion, to name a few physiological functions. Furthermore, intracellular organelle membrane ion channels are critical for controlling cytoplasmic calcium content and acidification of certain subcellular compartments (e.g., lysosomes).

Ions flow in a passive manner through channels on their way to equilibrium. Electrical (voltage) or chemical (concentration) gradients can cause this movement. Ion channels' ability to adjust ion flow may have provided an evolutionary advantage by allowing single-celled creatures to regulate their volume in response to environmental changes. Ion channels have evolved to play critical functions in cellular secretion and electrical signaling over time (Chen and Yada, 2011).

The movement of charged ions through open channels constitutes an electrical current that alters the charge distribution across the membrane and thus affects the voltage across the membrane. Voltage-gated channels in excitable cells allow temporary inflow of positive ions (e.g., sodium, and calcium ions) and are responsible for action potentials, which are short depolarizations of the membrane. Action potentials can be conveyed quickly over great distances, allowing for physiological output synchronization and exact timing. Action potentials open voltage-gated calcium-selective ion channels and raise intracellular calcium concentrations in almost all cases, triggering downstream physiological actions such as secretion or muscle contraction.

Ion Conductors

Ionic conductivity is a metric for a substance's proclivity for ionic conduction. The transfer of an iron from one place to another through imperfections in the crystal lattice of a solid or aqueous solution is referred to as ion transport. Ionic conduction is one of the current's mechanisms. Ions in solids are usually fixed in their places in the crystal lattice and do not migrate. Ionic conduction, on the other hand, can occur, especially when the temperature rises. Batteries are made of materials that have this feature.

Fast ion conductors are solid conductors with highly mobile ions in materials science. These materials, also described as solid electrolytes and super-ionic conductors, are essential in the field of solid-state Ionics. Batteries and various sensors can benefit from these materials. Solid oxide fuel cells primarily use fast ion conductors (Doubleday, 2007). They facilitate ion transportation without the use of a liquid or soft membrane between the electrodes because they are solid electrolytes. The effect is based on the hopping of ions across a crystal structure that is otherwise stiff.

Until recently, ionic conduction in polymers was thought to be an undesirable phenomenon that caused poor insulating qualities. As a result, studies of intrinsic conductivity (the residual conductivity after eliminating the final remnants of any ions or ionizable contaminants) can be found in earlier literature. The opposing goal of enhancing ionic conductivity for particular applications like as batteries or fuel cells with elastomeric electrolytes is attracting a lot of attention these days. This is owing to the observation that the figure of merit for most applications is the conductivity divided by the square of the electrolyte thickness, rather than the conductivity itself.

Elastomers' outstanding film-forming characteristics, along with their low conductivity, make them ideal candidates for use as novel materials in electrochemical devices. Because most polymers are essentially organic and contain ions only incidentally in extremely minute concentrations, they are poor ionic conductors. A purposeful insertion of ions into an environment that allows for great mobility is required for good ionic conductivity.

J

Junctions

In multicellular animals, cell-cell communication is essential for cell differentiation, morphogenesis, cell proliferation, and homoeostasis. It has been called "the song that the nucleus hears," and when it is off, aberrant cell communication can disturb biological processes. Tight junctions, anchoring junctions (hemidesmosomes, focal adhesions, desmosomes, and adherens), and communication junctions are all essential components of cell-cell communication (chemical synapses, ion channels, pannexins, and gap junctions) (Figure 20).

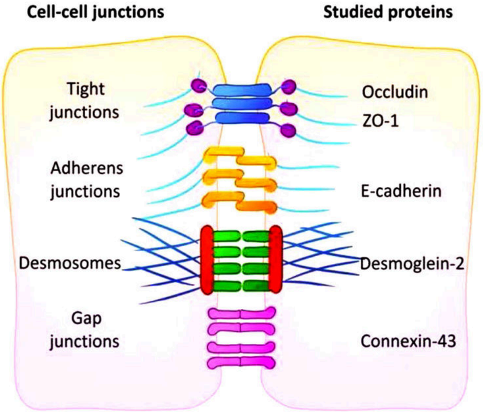


Figure 20. In mammals, cell junctions (also known as intercellular bridges) are multiprotein complexes that allow contact or adhesion between nearby cells or

between a cell and the extracellular matrix. In epithelial tissues, cell connections are very plentiful.

Source: https://www.researchgate.net/figure/A-summary-of-cell-cell-junctions-with-representative-proteins-The-abundance-of-five_fig2_347409272.

Gap junctions are important in a variety of physiological activities, such as heart electrical activity, neural signaling, hormone secretion, auditory function, wound healing, immunological functioning, inflammatory illnesses, and bone remodeling. Furthermore, by cGAMP transfer, gap junctions increase the brain metastasis of cancer into astrocytes. The mouth cavity and its appendices are subjected to a complex environment as well as significant mechanical stress (Ehdaie, 2007).

The mouth cavity and its appendices are subjected to a complex environment as well as significant mechanical stress. Various cell-cell and cell-extracellular matrix junctions provide tight polar interconnections between epithelial cells, which safeguard the oral mucosa from microbial infections and wear and tear. However, in comparison to their well-known roles in physiological processes, the functions of gap junctions in oral tissues under normal and pathological situations have yet to be fully investigated. As a result, the significance of gap junctions in oral development and disease is an important factor.

K

Khaki Goo

Khaki goo (sometimes written gray goo) is a possible global disaster scenario using molecular nanotechnology in which out-of-control self-replicating machines consume all biomass on Earth while constructing more of themselves, a scenario known as ecophagy ("eating the environment," more literally "eating the habitation"). The original concept thought that machines were built to have this capability, whereas popularizations assumed that machines might acquire it by chance.

Drexler recently admitted that there is no need to construct anything that resembles a possible runaway replication. This would completely eliminate the issue. He argues in research published in the journal Nanotechnology that self-replicating machines are overly complicated and inefficient. Nanosystems: Molecular Machinery, Manufacturing, and Computation, his technical book on advanced nanotechnologies from 1992, presents manufacturing systems that are desktop-scale factories with specialized machinery in fixed positions and conveyor belts to carry parts from place to place. None of these safeguards would stop a group from developing a weaponized gray goo if such a thing existed (Farokhzad and Langer, 2009).

As a result, it is a useful tool in the field of technological ethics. It was used as a worst-case scenario thought experiment by Daniel A. Vallero for technologists thinking about the risks of expanding a technology. This necessitates including even extremely low probability occurrences in a decision tree or event tree if such events may have an exceedingly unfavorable and irreversible impact, i.e., application of the precautionary principle. "Any miscalculation in science will have a rippling effect," Dianne Irving warned (Figure 21).

Figure 21. Gray goo is a useful construct for thinking about high-impact, low-probability outcomes from developing technologies.

Source: https://yoo.rs/nanotechnology-gray-goo-will-nanotechnology-kill-us-or-save-us-1589585485.html.

Knowledge Bots

Knowledge-based bots compile real-time data from your company into a centralized, intelligent repository, allowing you to obtain answers from any touchpoint. The bot also learns what is popular and what is lacking, thanks to artificial intelligence (AI), so your team understands what content to develop next. This type of technology can alter your customer experience on a number of levels if your organization is sophisticated or fast-paced.

APIs bring knowledge together into a single source of truth, which is how knowledge bots work. Share from a single location over the web, phone, chat, and social media. Design an interface in your brand's style or use a standard layout. Easily segment and manage knowledge for various audiences. SaaS (Software as a Service) on the cloud Understands and responds to client sentiment and feedback with a 97% accuracy rate (Gupta, 2011).

Customers and employees gain from a better, more intuitive experience; calls are reduced by 60% and emails are reduced by 55%; staff training is reduced from 6 weeks to 1 week; and knowledge gaps in existing resources are identified and fixed. Knowledge-based bots may offer value to any organization, but they are especially useful in areas like travel, utilities, and public services, which rely on a variety of different knowledge sources, high volumes, and various touchpoints.

L

Laser Method

Laser treatments are medical procedures that make use of concentrated light. Light from a laser (which stands for light amplification by stimulated emission of radiation) is adjusted to certain wavelengths, unlike light from most other sources. It can then be focused into powerful beams as a result. Laser light is so powerful that it can be used to cut steel or shape diamonds. Lasers in medicine allow surgeons to work with extreme accuracy by concentrating on a small area and causing less damage to the surrounding tissue. When compared to standard surgery, laser therapy may result in less pain, swelling, and scars. Laser therapy, on the other hand, can be costly and requires multiple treatments.

Some of its applications include shrinking or destroying tumors, polyps, or precancerous growths, relieving cancer symptoms, removing kidney stones, and removing a portion of the prostate. Lasers may be beneficial in the early stages of various malignancies. Laser therapy is frequently used in conjunction with other cancer treatments such as surgery, chemotherapy, or radiation. Laser therapy can also be used to eliminate moles, warts, skin tags, and sunspots, as well as hair, wrinkles, scars, and wounds. It can even be used to remove tattoos (Gunasekaran et al., 2014). Cosmetic skin and eye operations, for example, are termed elective laser surgeries. Some people believe that the hazards of undergoing these procedures outweigh the advantages. Laser procedures, for example, may aggravate some health or skin issues. Poor general health raises your risk of problems, just as it does with traditional surgery.

Lab-on-a-Chip (LOC) Devices

A lab-on-a-chip (LOC) is a device that combines one or more laboratory tasks on a single integrated circuit (often referred to as a "chip") that is only a few square centimeters in size, allowing for automation and high-throughput screening. LOCs are capable of handling fluid volumes as small as picoliters. Microelectromechanical systems (MEMS) devices, sometimes known as "micro total analysis systems," are a subset of LOC technologies.

Microfluidics, the physics, control, and study of tiny quantities of fluids, may be used by LOCs. However, properly defined "lab-on-a-chip" refers to the scaling of one or multiple lab operations to chip-format, whereas "TAS" refers to the integration of the entire sequence of lab activities in order to execute chemical analysis. When it was discovered that TAS technologies might be used for more than only analysis, the term "lab-on-a-chip" was coined (Huang et al., 2010).

LOC technology could soon play a big role in attempts to improve global health, especially with the introduction of point-of-care testing devices. Infectious infections that would be treated in a developed country are often fatal in countries with limited healthcare resources. Poor healthcare facilities can have the drugs to treat a specific ailment but lack the diagnostic equipment to identify the people who should receive the drugs. LOC technology, according to many academics, could be the key to developing powerful new diagnostic equipment.

These researchers hope to develop microfluidic chips that will enable healthcare professionals in under-resourced clinics to perform diagnostic procedures such as microbial culture assays, immunoassays, and nucleic acid assays without the use of a laboratory. Pollen tube guiding in Arabidopsis thaliana could be studied using LOC technologies. Plant on a chip is a miniature device that can be used to incubate pollen tissues and ovules for plant science research.

Langmuir-Blodgett (LB) Films

When Langmuir films—or Langmuir monolayers (LM)—are transported from the liquid-gas interface to solid supports during the vertical transit of the support through the monolayers, a Langmuir–Blodgett (LB) film is created. One or more monolayers of organic material produced from the top of a liquid onto a solid substrate by immersing (or Emersion) the solid substrate into (or out of) the liquid can be found in LB films. With each immersion or emersion process, a monolayer is adsorbed uniformly, allowing for the formation of films with highly precise thickness. Because the thickness of each monolayer is known, it can be put together to get the entire thickness of a Langmuir–Blodgett film (Figure 22).

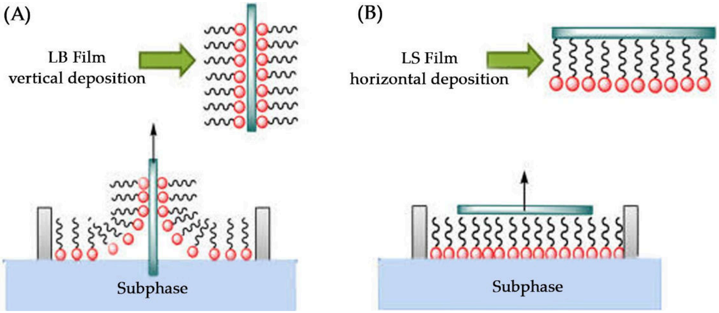


Figure 22. Langmuir films are made when a monolayer is produced at the gas-liquid or liquid-liquid interface. When a Langmuir film is deposited on a solid surface, it is referred to as a Langmuir-Blodgett or Langmuir-Schaefer film (in the case of vertical deposition) (in the case of horizontal deposition).

Source: https://www.sciencedirect.com/science/article/pii/B9780323497824000048.

When amphiphilic (surfactant) molecules or nanoparticles are dispersed on water at an air-water contact, Langmuir films form. Surfactants (also known as surface-acting agents) are hydrophobic compounds with hydrophilic heads and hydrophobic tails. Surfactant molecules arrange themselves when their concentration is less than the minimum surface concentration of collapse and they are fully insoluble in water. Surface-energy concerns can account for this trend (Kandel et al., 2013). Because the tails are hydrophobic, they prefer to be exposed to air rather than water. The head-water interaction is also preferable to the air-water interaction because the heads are hydrophilic. The total result is a decrease in surface energy (or equivalently, surface tension of water).

Many potential applications for LM and LB films have been proposed throughout the years. Extremely thin films and a great degree of structural order are two of their distinguishing features. These films, which are made up of certain organic compounds, exhibit a variety of optical, electrical, and biological properties. In general, organic substances exhibit stronger positive reactivity to external influences than inorganic materials (pressure, temperature, or gas change). Half of a cellular membrane can also be modeled with LM films.

Biological membranes can also be made using LB films. Because they are naturally adapted to the Langmuir method of film formation, lipid molecules with the fatty acid moiety of long carbon chains connected to a polar group have garnered a lot of interest. This type of biological membrane can be used to explore drug action mechanisms, permeability of physiologically active chemicals, and biological system chain reactions.

Lattice LED (Light-Emitting Diode)

When current passes through a light-emitting diode (LED), it produces light. Electrons recombine with electron holes in the semiconductor, producing energy in the form of photons. The energy needed for electrons to pass the semiconductor's bandgap determines the hue of light (equivalent to the energy of photons). Multiple semiconductors or a coating of light-emitting phosphor on the semiconductor device are used to produce white light.

The first LEDs, which appeared as functional electrical components in 1962, emitted low-intensity infrared (IR) light. Remote-control circuits, such as those found in a wide range of consumer gadgets, utilize infrared LEDs. The original visible-light LEDs had a low intensity and were only available in red. Early LEDs were commonly employed as indicator lamps and in seven-segment displays, replacing small incandescent bulbs (Kaur et al., 2014).

LEDs with high, low, or intermediate light output, such as white LEDs ideal for room and outdoor area lighting, have recently been developed in visible, ultraviolet (UV), and infrared wavelengths. LEDs have also spawned new kinds of displays and detectors, and their high switching rates are beneficial in sophisticated communication devices, with various applications as aviation lighting, fairy lights, automotive headlights, advertising, general lighting, traffic signals, flash photography, lighted wallpaper, gardening grow lights, and medical equipment.

LEDs have a number of advantages over incandescent light sources, such as lower energy consumption, a prolonged lifetime, increased physical resilience, reduced size, and faster switching. Electrical limits to low voltage and primarily to DC (not AC) power, difficulty to deliver consistent lighting from a pulsating DC or an AC electrical supply source, and lower maximum functioning temperature and storage temperature are some of the downsides of LEDs.

Visual signals, in which light travels more or less straight from the source to the human eye to deliver a message or meaning, are one of the four basic types of LED applications. When light is reflected from objects, it gives these items a visual reaction. Narrowband light sensors, which function in a reverse-bias mode and responding to incident light rather than emitting light and measuring and engaging with processes that do not require human eyesight.

Liposome

Liposomes are tiny spherical artificial vesicles made from cholesterol and non-toxic phospholipids. Liposomes are attractive drug delivery devices due to their size, hydrophilic, and hydrophobic properties (along with biocompatibility). Liposome characteristics vary greatly depending on lipid composition, surface charge, size, and manufacturing process (Kung and Kung, 2004).

When phospholipids are hydrated in aqueous solutions, they spontaneously form closed structures, according to research. Depending on the nature of the medications, such vesicles with one or more phospholipid bilayer membranes can transport aqueous or lipid pharmaceuticals. Because lipids are amphipathic in aqueous conditions (both hydrophobic and hydrophilic), their thermodynamic phase qualities and self-assembling properties impact the entropically focused accumulation of their hydrophobic sections into spherical bilayers.

Liposomes are spherical vesicles with sizes varying from 30 nanometers to several micrometers in size. They are made up of one or more lipid bilayers that enclose aqueous units, with the polar head groups arranged in the interior and outer aqueous phases' pathways. Self-aggregation of polar lipids, on the other hand, is not restricted to traditional bilayer forms that rely on molecule shape, heat, and environmental and preparatory conditions, but can also self-assemble into a variety of colloidal particles (Klimeck et al., 2008). Liposomes are widely employed in the beauty and pharmaceutical industries as carriers for a variety of compounds. Furthermore, the food and farming industries have extensively researched the use of liposome encapsulating to develop delivery systems that can entrap and protect unstable substances (such as antibacterial, antioxidants, tastes, and bioactive elements).

The newest delivery approach used by medical researchers to convey medications that work as curative promoters to the assured bodily parts is lipid encapsulation technology (LET). The distribution of important combinations to the body was the focus of this type of delivery system idea. LET is a technique for creating liposomes, which are sub-microscopic foams that encapsulate a variety of compounds. These 'liposomes' create a barrier surrounding their contents that is resistant to enzymes in the mouth and stomach, alkaline solutions, digestive fluids, bile salts, and intestinal flora, as well as free radicals, which are all produced in the human body. As a result, the contents of the liposomes are shielded from oxidation and destruction. Until the components of the liposome are transferred to the specific target gland, organ, or system where they will be used, the protective phospholipid shield or barrier stays intact.

Liquid Phase Separation

Liquid-liquid phase separation (LLPS) is a reversible, thermodynamically-driven event in which two distinct liquid phases with varying solute concentrations are separated. When produced by a liquid or a solid, a physically homogenous system consists of a single-phase and is referred to be condensed. Depending on the interactions between solute and solvent molecules, miscible components can reside in homogenous solutions or undergo de-mixing. Despite the entropic loss associated with the development of a two-phase system, phase separation can become energetically advantageous. LLPS is a thermodynamically driven, reversible phenomena that involves the de-mixing of a chemically homogeneous system into two distinct liquid phases with varying solute concentrations. Aside from temperature, pressure, pH, crowding agents, and other factors, the equilibrium between mixing and de-mixing is greatly influenced by component concentrations (Figure 23).

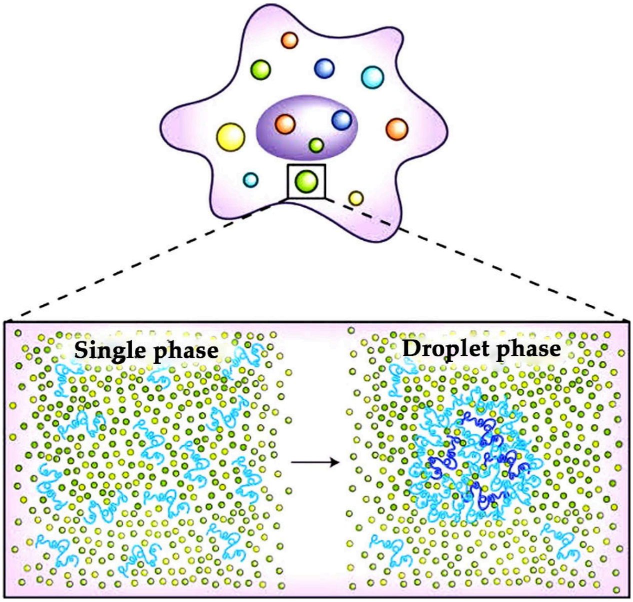


Figure 23. A basic liquid-liquid phase separation is demonstrated by our everyday experience with water and oil droplets (LLPS). Cells resemble liquid droplets in biology, with membrane-less compartments that are critical for concentrating chemicals and aiding spatiotemporal modulation of cellular processes.

Source: https://www.nature.com/articles/s41592-018-0269-7.

It is important to note that phase separation in a liquid system does not always imply phase transition (i.e., a change in state from liquid to solid), however, the latter can occur during the "maturation" of liquid biological condensates. A phase diagram can be made by carefully screening variables like as temperature and concentration to find the region where phase separation occurs (Lakhal and Wood, 2011).

Liquid droplets can merge and consolidate, experiencing Ostwald ripening (i.e., larger droplets develop at the cost of smaller ones), and dripping in the phase separation regime, depending on their density and viscosity tension. For materials of distinct chemical nature (hydrophobic/hydrophilic), such as oily materials and water, which are notoriously immiscible, a "phase behavior" can be easily determined. The partition coefficient (K) of immiscible compounds is computed as the ratio of concentrations of a chemical in a mixture of two immiscible solvents at equilibrium.

The increased interest in LLPS has fueled research aiming at acquiring structured and knowledgeable information on proteins undergoing LLPS, as well as giving a broad array of information on the biophysical driving factors, biological function, and control of these systems.

Lithography

Lithography is a planographic printing technique that takes advantage of grease and water's immiscibility. Ink is transferred to a grease-treated image on a flat printing surface in the lithographic technique; non-image (blank) portions, which retain moisture, reject the lithographic ink. This inked surface is subsequently printed, either straight on paper or onto a rubber cylinder, using a specific press (as in most fine-art printmaking) (as in commercial printing).

The use of a block of porous limestone was the earliest—though no longer the only—method of producing lithographs. Since Senefelder's time, the procedure of preparing such stones for hand printing has remained largely unaltered. In practically every way, the materials and processes of the 19th-century lithographer are replicated by the contemporary hand printer. Before the printing surface is glued, moistened, and inked in preparation for printing, an image is made using tusche (a carbon pigment in liquid form) and litho crayon (Lieber, 2003).

The printing itself is done on a press that scrapes or slides the paper. A single stone may produce an almost infinite number of duplicates because of its lack of wear in printing, yet in art printmaking, only a limited number of prints are extracted, signed, and numbered before the stone is "canceled" (defaced). Although many artists favor the time-honored method, techniques discovered in the 20th century greatly altered the procedure.

The inked picture is first printed on a rubber cylinder, which then offsets, or transfers, the image to paper or other materials in the offset process, which is by far the most widespread method in use. Offset lithography can print on leather, fabric, wood, tin, and rough or smooth paper because to the flexibility of the rubber cylinder. Stamps, billboards, posters, maps, newspapers, magazines, books, letterheads, booklets, greeting cards, calendars, labels on cans, packaging, and other advertising matter were all printed in great quantities using offset printing in the past.

On a modern rotary offset press, lithographic printing can generate high-quality, finely detailed impressions at high speeds. Any material that can be photographed in the platemaking process can be reproduced. As a result, it produces more than 40% of all print, packaging, and publication, which is more than twice the percentage produced by any other single printing method.

Luminescence

The emission of light by some materials when they are relatively cool is known as luminescence. In contrast, incandescent bodies emit light, such as burning coal or wood, molten iron, and wire heated by an electric current. Neon and fluorescent lamps, television, radar, and X-ray fluoroscopy screens, organic substances like luminol or the luciferins in fireflies and glowworms, certain pigments used in outdoor advertising, and natural electrical phenomena like lightning and the aurora borealis are all examples of luminescence. Because light emission does not occur when the material is above room temperature in any of these processes, luminescence is commonly referred to as cold light (Lü et al., 2009).

Neon and fluorescent lamps, X-ray fluoroscopy screens, radio, and television, organic substances like luminol or the luciferins in glowworms and fireflies, certain pigments used in outdoor advertising, and natural electrical phenomena like lightning and the aurora borealis are all examples of luminescence. Because light emission does not occur when the material is above room temperature in any of these processes, luminescence is commonly referred to as cold light. The ability of luminous materials to convert unseen types of energy into visible light is its practical utility.

After a suitable material absorbs energy from a source such as UV or X-ray radiation, electron beams, chemical processes, and so on, luminescence emission happens. Since excited states are transitory, the energy lifts the atoms of the substance into an excited state, and then the material undergoes another transformation, down to its unexcited ground state, where the absorbed energy is released as light, heat, or both (all discrete energy states, including the ground state, of an atom are defined as quantum states) (Figure 24).

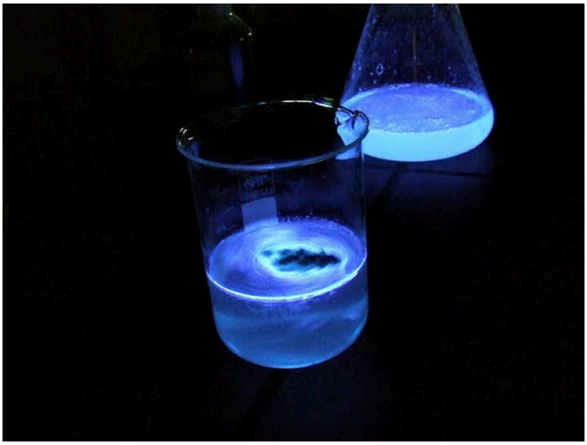


Figure 24. When certain minerals are subjected to low-powered sources of ultraviolet or infrared electromagnetic radiation (such as portable UV lamps) at atmospheric pressure and temperatures, they glow.

Source: https://en.wikipedia.org/wiki/Luminescence.

Just the outermost electrons revolving around the nuclei of the atoms are excited. The degree of transfer of excitation energy into light determines luminescence efficiency, and only a few substances have high enough luminescence efficiency to be useful. Cold-body radiation is what it is. Chemical interactions, electrical energy, subatomic vibrations, and crystal tension can all cause it. This differentiates luminescence from incandescence, which occurs when a material is heated and emits light. Radioactivity was once supposed to be a type of "radio-luminescence," but it is now considered distinct because it involves more than electromagnetic radiation (Manjunatha et al., 2016).

M

Molecular Electronics

The study and application of molecular building blocks for the production of electronic components is known as molecular electronics. It is a multidisciplinary field encompassing physics, chemistry, and materials science. The usage of molecular building blocks to construct electronic components is the common thread. The possibility of size reduction in electronics given by molecular-level property control has sparked a lot of interest in molecular electronics. It offers a way to push Moore's Law past the expected boundaries of small-scale traditional silicon integrated circuits (ICs).

Molecular electronics works at distances of less than 100 nanometers in the quantum domain. Miniaturization to the level of single molecules reduces the scale to a point where quantum mechanics effects become significant. Unlike in traditional electronic components, where electrons can be filled in or taken out in a more or less continuous flow of electric charge, the transfer of a single electron has a major impact on the system (Marcato and Durán, 2008). When calculating the electrical properties of the setup, the substantial quantity of energy due to charging must be taken into consideration, and it is particularly sensitive to distances from surrounding conducting surfaces.

The first-time molecular electronics was referenced in history was in 1956 by Arthur Von Hippel, a German physicist who proposed a bottom-up method of building electronics from atoms and molecules instead of premade components, which he called molecular engineering. Many people regard Ratner and Aviram's 1974 article to be the first breakthrough in the subject. They provided a theoretical computation of transport through a redesigned charge-transfer molecule with donor-acceptor sites that would enable only one-way transport, similar to a semiconductor diode, in a paper titled Molecular Rectifiers.

The development of electrically comparable molecular components has sparked new study. Conducting polymers, photochromics, organic superconductors, electrochromic, and other electrical and photonic applications have all benefited from moletronics. Because the size of a silicon chip must be reduced, achieving such technology at the molecular level is critical. Despite the fact that experimental verification and modeling of molecular devices is a difficult endeavor, significant progress has been made in this sector.

Molecular Machine

A molecular machine, also known as a nanite or nanomachine, is a molecular element that responds to certain stimuli by producing quasi-mechanical movements (output) (input). Macromolecular machines are often used in cellular biology to conduct functions that are critical to life, such as DNA replication and ATP generation. The term is frequently used to describe molecules that essentially imitate activities that happen at a macroscopic level. The term is also commonly used in nanotechnology, where several highly complex molecular machines have been suggested with the goal of building a molecular assembler (Mei et al., 2011).

For years, analytical chemists and scientists have worked to miniaturize devices found in the macroscopic world, with varied degrees of success. The study of molecular machineries is at the forefront of cellular biology. For the concept and production of molecular machines, the Nobel Prize in Chemistry was given to Jean-Pierre Sauvage, Sir J. Fraser Stoddart, and Bernard L. Feringa in 2016. Artificial and biological molecular machines are the two primary groups of molecular machinery. Artificial molecular machines (AMMs) are molecules that have been developed and manufactured artificially, whereas biological molecular machines are present in nature and have evolved into their current forms during abiogenesis on Earth.

Chemists have created a wide range of AMMs that are very basic and small in comparison to biological molecular machines. Sir J. Fraser Stoddart invented the first AMM, a molecular shuttle. A molecular shuttle is a rotaxane molecule with two bulky stoppers mechanically linked onto an axle. With diverse stimuli like as light, pH, solvents, and ions, the ring can migrate between two binding sites (Mitter and Hussey, 2019).

Theoretical and practical work on the development of more complicated molecular machines is ongoing. Several molecules, such as molecular propellers, have been developed, however experimental studies of these molecules are hampered by a lack of ways to produce them. Theoretical modeling can be quite beneficial in this context for understanding the self-assembly/disassembly processes of rotaxanes, which are crucial for the building of light-powered molecular machines. This molecular-level understanding could pave the way for the development of increasingly complex, diverse, and effective molecular machines for nanotechnology applications, such as molecular assemblers (Figure 25).

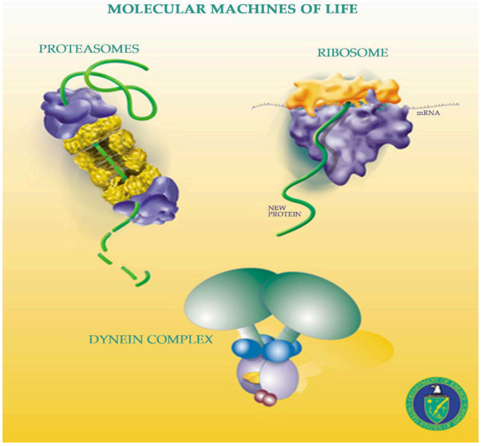


Figure 25. The term is frequently used to describe molecules that essentially imitate functions that occur at a macroscopic level. The word is also commonly used in nanotechnology, where several highly complicated molecular machines have been developed with the goal of building a molecular assembler.

Source: https://www.wikiwand.com/en/Molecular_machine.

Transport at the molecular level, modification of nanostructures and chemical systems, high density solid-state data processing, and molecular prosthetics are some prospective uses of molecular machines, albeit they are currently not viable. Before molecular machines can be employed in practice, many fundamental obstacles must be addressed, including autonomous operation, machine complexity, machine synthesis stability, and working circumstances (Mousavi and Rezaei, 2011).

Molecular Manipulator

Several parts of condensed matter physics, physical chemistry, and material science have lately fused into the multidisciplinary subject of nanotechnology and nanoscience, thanks to major advancements in these domains in recent decades. Among the most important topics of nanotechnology and nanoscience is molecular self-assembly. The goal of molecular self-assembly research is to develop advanced functional materials and devices by manipulating molecules and determining their structures, as well as their physical and chemical properties.

Separating old chemical connections and then creating new ones, as well as adjusting weak non-covalent connections to generate self-assembled complexes, are some of the molecular assembly processes. Covalent-based and non-covalent-based self-assemblies are the terms used. Self-assembly is often referred to as supramolecular chemistry because it is one of the most common methods for developing novel materials. The chemistry of developing novel functional substances via self-assembly and studying the molecular assembly mechanisms of this procedure is referred to as supramolecular chemistry. Supramolecular systems with sizes ranging from 1 nanometer to tens of nanometers (NMs) have been created (Morrow et al., 2007).

In comparison to traditional ensemble methods, investigating macromolecules at the single-molecule level can yield incredibly clear and even surprising perspectives of biological reactions. Single-molecule techniques have advanced at a breakneck pace over the last two decades, and these cutting-edge technologies have transformed biological research by allowing for single-molecule manipulation and detection.

Molecular Manufacturing

Any use of nanoscale (very small) tools and non-biological processes to manufacture objects, equipment, and networks at the molecular level is referred to as molecular manufacturing. The size of nanoscale items is on the order of a few NM, with 1 nm equaling a billionth of a meter (1.0 × 10-9 meters). Nanoscale technology, a major part of nanotechnology in which standard-sized tools are used to produce simple structures and equipment, is not the same as molecular manufacturing.

Molecular nanotechnology would use original definitive methods to acquire definitive outcomes, whereas conventional chemistry uses inexact processes to obtain inexact results and biology employs inexact processes to obtain definitive results. In molecular nanotechnology, the goal is to balance molecular processes in positionally controlled locations and orientations to achieve desired chemical changes, and then to build systems by combining the reactions' products (Mnyusiwalla et al., 2003).

Water filtration, sanitation, farming, renewable fuels (especially photovoltaics), house, and business construction, computer manufacture, communications, and medical are among potential applications of nanotechnology. Economic instability, misuse by people or groups with evil intent, the emergence of excessive governmental regulation, morality debates, and environmental damage are among hazards associated with nanotechnology.

Molecular manufacturing has the potential to completely transform our world's economies. Many manufacturing industries may become outdated, and society as a whole may be irreversibly changed. Molecular manufacturing has the potential to usher in a new industrial revolution that fundamentally alters the way we do business. Simultaneously, similar advancements may make it simple and inexpensive to create devastating weapons. Nanotechnology is sometimes referred to as a "disruptive" technology because of its propensity to make such radical changes.

Sensors that are smaller than blood cells, for example, might be made cheaply. These sensors, if put in huge quantities into a patient's bloodstream, might provide extremely accurate diagnosis. Nano-robots could be created via molecular manufacturing to undertake more accurate surgical procedures. Such nano-robots could avert most of the damage caused by the clumsy scalpel by acting at the cellular level (Mnyusiwalla et al., 2003).

In around 20 years or so, molecular fabricators may be accessible to anyone, anyplace. Any item whose design has been programmed into fabricators can be made cheaply and in huge quantities when fabricators are accessible. This might greatly improve living circumstances in areas where manufactured items are difficult to come by. Water filters, for example, might be manufactured to aid locations with tainted water supplies, while solar cells may provide electricity to even the most isolated forest or desert.

There are three stages in the evolution of molecular manufacturing, each with its own set of capabilities. The computer-controlled creation of exact molecular structures is the initial stage. The second step employs nanoscale tools to create additional tools, allowing the manufacturing base to expand exponentially. The third level, which involves integrating nanoscale items into larger structures, leads to desktop "nanofactories" capable of producing complex products.

The implications of distributed general-purpose production of high-performance items are numerous. It would be difficult to regulate the production of weapons, other forms of vice, and intellectual property (IP) infringement. Attempts at regulation that are too clumsy could result in an intractable black-market infrastructure. The lessening of logistical limitations, as well as rapid improvements in robotics and aerospace, could have military repercussions. A shift in industrial raw material uses and manufacturing site, if extensively adopted, might have an impact on resource output and international trade patterns.

On the plus side, widespread adoption of low-cost yet sophisticated technologies might soon replace inefficient or non-existent infrastructure (Xia, 2008). Advanced components and materials may make space access less expensive and more convenient. Medical research and health care could benefit from rapid prototyping and manufacture of nanoscale devices (Figure 26).

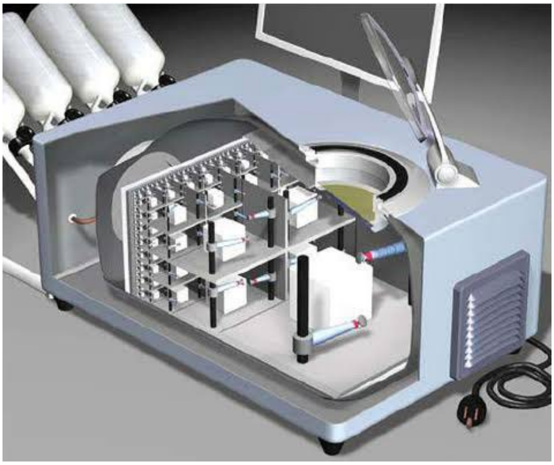


Figure 26. Molecular manufacturing, according to researchers, has the ability to change medicine as well.

Source: https://www.researchgate.net/figure/Proposed-desktop-scale-molecular-manufacturing-appliance_fig2_233549494.

Because the risks and rewards of molecular manufacturing are so high, and because it can be created step by step using today's technologies, it is critical that we learn more about the timeline, capabilities, and practical ramifications. Although the most transformational and harmful outcomes are dependent on the most advanced stage of development, early success may lead to shockingly rapid development of more advanced skills. There are various areas of research that can help us better comprehend molecular manufacturing's potential. This research can and should start right now.

Molecular Medicine

Biological, chemical, physical, bioinformatics, and medical approaches are utilized to describe molecular structures and mechanisms, discover fundamental molecular and genetic mistakes of disease, and create molecular therapies to remedy them in the discipline of molecular medicine. Instead of the previous theoretical and practical focus on patients and their organs, the molecular medicine paradigm stresses cellular and molecular processes and interventions (Weiss et al., 2020).

In European universities, molecular medicine is a relatively recent scientific discipline. It provides a link between the two subjects by combining modern medical studies with the study of biochemistry. Only a few universities now offer the subject to undergraduates. A graduate with a degree in this field can work in medical professions, science, and research, laboratory work, or pursue continuing medical education degrees. Gene expression, research methodologies, proteins, research in cancer, immunology, biotechnology, and many other topics are common in core subjects, which are similar to biochemistry courses. In some universities, molecular medicine is taught alongside another subject, such as chemistry, as a supplement to the undergraduate curriculum.

Linus Pauling, Harvey Itano, and their collaborators set the framework for the science of molecular medicine when they published the key paper "Sickle Cell Anemia, a Molecular Disease" in Science magazine in November 1949. Roger J. Williams published Biochemical Individuality in 1956, a foresightful work on heredity, illness prevention and treatment on a molecular level, and nutrition, which is now known as individualized medicine or orthomolecular medicine. Pauling proposed and described this approach of molecular medicine, which focuses on natural and nutritional components used for treatment and prevention, in a study published in science in 1968.

Molecular medicine strives to diagnose and manipulate illness and health-related molecular processes. Knowledge of the biological operation of humans at the most fundamental level is central to all of its actions. Only the combination of biological research, nanotechnology, and information and communications technology has made this level of knowledge and the ability to intervene in these processes possible.

The current research on molecular medicine links molecular medicine to five distinct, but sometimes interconnected, goals. (i) Early and more reliable disease diagnosis: It is claimed that molecular diagnostic instruments can detect very low amounts of biochemical chemicals, signaling the start of disease processes. (ii) Molecular devices may potentially help customize treatments to the molecular properties of a patient's condition, improving prognostic reliability and decreasing over-/under-treatment. (iii) Increasing the efficacy of therapies: Advancing and enhancing the accuracy of diagnosis and prognosis may, of course, help to increase the efficacy of treatments (West and Halas, 2000). However, molecular medicine has the potential to directly increase the efficacy of medicines. For example, drugs for brain tumors that combine nanoparticles with guiding molecules can cross the blood-brain barrier. (iv) Diagnostic and treatment methods that are less intrusive or burdensome: Nanotechnology allows for the miniaturization of medical instruments and devices for both diagnostic and therapeutic purposes. As a result, these gadgets are becoming less intrusive and are more easily transportable. (v) Monitoring health and tailored care: Because molecular diagnostics is neither intrusive nor burdensome, it allows for repeated monitoring of internal systems. For individuals on psychopharmaceutical drugs like lithium, a lab on a chip is now accessible. These individuals can evaluate their blood lithium levels on a regular basis and adjust their medicine dosage accordingly.

Molecular Nanotechnology

Richard Feynman's concept of microscopic factories with intricate machines to produce items is the foundation of molecular nanotechnology. It is concerned with the design of molecular-scale devices, as opposed to other aspects of nanotechnology such as nanoscale materials. Machines are created to exact, complicated atomic specifications using the mechanosynthesis method. For example, diamond mechanosynthesis has gotten a lot of attention in the last 10–15 years.

Molecular nanotechnology integrates principles from a variety of fields, including biophysics and chemistry, as well as systems engineering principles that govern the advancement of modern macro-scale processing plants. It draws on the molecular machinery of biological organisms and information systems principles that govern the advancement of modern macro-scale factories (Thompson, 2011). The molecular assembler, a tool that can build nanoscale machines atom by atom, is one example of a technology-related to the field. Mechanosynthesis-built nanoscale devices can be employed as smart materials, nano-sensors, self-replicating nanobots, medicinal nanobots, and phased-array optics, for example (Figure 27).

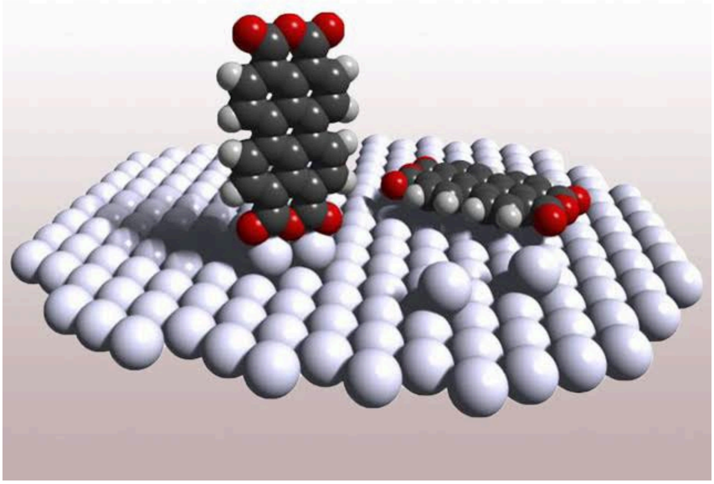


Figure 27. Molecular nanotechnology has the potential to be used in a variety of fields, assisting in the development of answers to pressing issues and providing researchers with new, cutting-edge tools that will propel science forward in the future.

Source: https://spectrum.ieee.org/amp/molecular-nanotechnology-takes-giant-leap-foward-by-manipulating-molecules-2650277224.

Smart materials that mirror human skin might be developed to be self-repairing, lowering maintenance costs, and decreasing safety concerns, while clever sensors could vary their behavior in response to the environment. Nanomedicine is one of molecular nanotechnology's most promising applications. Large numbers of medical nanobots could be used to quickly eradicate disease and offer patients with ultra-targeted pain alleviation. They might also be able to treat inherited diseases and potentially extend people's lives. However, this application of nanotechnology has created ethical problems.

Nano-machines and materials will be able to manufacture larger amounts of goods at a lower cost due to their microscopic size. Furthermore, a potential application is the creation of stronger and lighter materials that are an upgrade over commonly used steel and aluminum. Next-generation molecular computers will be possible, with greatly increased computational power. There is also the possibility of monetary gain. Molecular nanotechnology would almost eliminate the scarcity of produced items and make much more possible, benefiting both emerging and developed countries' economies.

Molecular nanotechnology, like the rest of the field of nanotechnology, is fraught with dangers. One risk related with the field is the development of new biological weapons; technologies may have the capacity to proliferate in the human body, similar to viruses and bacteria. The long-term consequences of using this technology have been extensively studied, leading to apprehension over its application (Arora et al., 2014).

Molecular Recognition

Noncovalent bonding like van der Waals forces, hydrophobic forces, metal coordination, hydrogen bonding, interactions, halogen bonding, or resonant interaction effects are used to describe the unique interaction between two or more molecules. Solvents can have a significant indirect role in triggering molecular recognition in solution, in addition to these direct interactions. Molecular complementarity exists between the host and the guest in molecular recognition. Only molecular containers, such as nanotubes, have gateways that fundamentally govern selectivity.

Molecular recognition occurs between receptors and ligands, antigens, and antibodies, DNA, and lectin, sugar, and protein, and RNA and ribosomes, among other biological systems. The antibiotic vancomycin, which selectively binds to peptides with terminal D-alanyl-D-alanine in bacterial cells via five hydrogen bonds, is a good example of molecular recognition. Vancomycin is harmful to bacteria because it binds to these peptides and prevents them from being used to build the bacteria's cell wall.

According to new research, molecular recognition elements may be synthesized at the nanoscale, eliminating the necessity for naturally occurring chemical recognition elements in the development of tiny molecule sensing tools. The coupling of biomimetic polymers to synthetic fluorescent nanomaterials can yield synthetic macromolecular complexes that function as synthetic antibodies for optical protein detection and recognition.

Chemists have proved that molecular recognition may be achieved in a variety of artificial supramolecular systems. Crown ethers, which can selectively bind particular cations, are one of the earliest examples of such a system. Since then, a lot of artificial systems have been developed (Sozer and Kokini, 2009).

The association constant of a second guest with a second binding site is affected by the attachment of the first guest to the first binding site of a host in dynamic molecular recognition. This results in cooperative binding. The attachment of the first guest raises the association constant of the second guest in positive allosteric systems. The binding of the first guest diminishes the association constant with the second in negative allosteric systems. Because it provides a method to regulate binding in biological systems, the dynamic aspect of this form of molecular recognition is particularly significant.

Molecular recognition is described as a phenomenon of organization in a recent study based on molecular simulations and compliance constants. Even if the strength of each individual hydrogen bond is precisely understood, the identification mechanism for tiny compounds like carbohydrates cannot be anticipated or engineered. However, reliable prediction of molecular recognition events requires more than a single frame snapshot between the guest and the host. Entropies are important contributors to binding thermodynamics and must be considered in order to forecast the recognition process more correctly. In single bound structures, entropies are rarely visible (static snapshot).

Molecular Repair/Surgery

Cutting and suturing are used to remodel a nose or ear in traditional surgery, which can result in extensive recovery times and scars. Researchers have now created a "molecular surgical" procedure that combines tiny needles, electrostatic force, and 3D-printed molds to alter living tissue swiftly and without incisions, scars, or recovery period. Even as a noninvasive substitute to laser eye surgery, the technology shows potential as a way to treat immobile joints (Abolmaali et al., 2013).

"Molecular neurosurgery" is a revolutionary medical concept that combines two partners: (i) a molecular neurosurgery drug, and (ii) the cognate receptor, which when activated causes the targeted elimination of a subset of neurons in which this receptor is endogenously expressed. In general, a molecular surgery drug is a selective and powerful ligand, and the target is a specific cell type that the molecular surgery technique is designed to eliminate. Due to the highest receptor density in their plasma membrane, these target cells have the highest intrinsic sensitivity to the molecular surgical agent. The engagement between the ligand and its receptor causes the receptor to become overactive. If the receptor is a ligand-activated non-selective cation channel, overactivity causes an excess of Ca^{2+} and Na^{+} to enter the cell, eventually leading to cell death (Figure 28).

Figure 28. In today's world, logical, and mechanism-based uses of technologies based on specialized molecular surgical agents can take the place of prior empiric techniques.

Source: https://www.industrytap.com/molecular-surgery-reshapes-living-tissue-without-surgery/48533.

For hundreds or thousands of years, pungent compounds such as allyl-isothiocyanate, piperine, gingerol, CAP (i.e., mustard, black pepper, ginger, and chili pepper, respectively) and other phytochemicals from spices have been repeatedly exposed to the skin and gastrointestinal system.

RTX has also been used in humans since ancient times, whether by accident or on purpose. After removing a tooth, tribal witchdoctors in Africa applied latex from various Euphorbia species to the wound to reduce pain and inflammation. A variety of pungent vanilloids, according to research, are used to augment our everyday meals. Various Hungarian recipes are made entirely of hot peppers, exposing the human body to vanilloids on a regular basis. Different pungent bioactive substances that target either the TRPV1 or TRPA1 channels are employed in Asia's regular diet as well. As a result, many of the substances discussed in this chapter are provided to humans, first as folk medicine, later in medical practice, either through frequent consumption or empiric administration (Smith et al., 2013).

Molecular Systems Engineering

Molecular engineering is a new branch of research that focuses on designing and testing molecular properties, behaviors, and interactions in order to create better materials, structures, and procedures for specific purposes. This approach falls under the broader concept of "bottom-up" design, in which observable aspects of a macroscopic system are altered by direct changing of a molecular structure.

Molecular engineering is a dynamic and expanding subject with complicated target issues; breakthroughs necessitate knowledgeable and creative engineers with cross-disciplinary knowledge. In contrast to the prevalent trial-and-error procedures used throughout engineering fields, a rational engineering process based on molecular concepts is used. A molecular design method aims to change system properties directly using a comprehension of their chemical and physical foundations, rather than depending on well-described but least understood empirical connections between the makeup of a system and its features. This frequently results in fundamentally novel materials and systems, which are needed to satisfy unmet demands in a variety of industries, including energy, healthcare, and electronics.

Furthermore, as technology has advanced, trial-and-error procedures are becoming increasingly costly and challenging, as it might be impossible to account for all significant connections among variables in a complex system. Computational tools, experimental methodologies, or a combination of both may be used in molecular engineering (Seil and Webster, 2012).

Many academic areas, including bioengineering, electrical engineering, chemical engineering, materials science, chemistry, and mechanical engineering, have used molecular design extensively. However, bringing together a sufficient mass of talent across disciplines to cover the realms of design theory and materials production, as well as device design and product development, is one of the major obstacles. As a result, while the concept of bottom-up rational engineering of technology is not new, it has yet to be widely converted into R&D initiatives.

Molecular engineers use advanced techniques and instruments to create and evaluate molecular and nanoscale interactions between molecules and the surfaces of objects. The complexity of molecules brought to the surface is increasing, and the techniques for analyzing surface features at the molecular level are evolving. Meanwhile, advances in high-performance computers have substantially broadened the application of computer simulation in molecular-scale systems research.

Molecule MWNTs Monolayer

Because of essential academic research and a wide range of potential applications such as I inhibition of corrosion, lubrication, adhesion, and micro-/nano-electronic devices, self-assembly of a molecular monolayer or nano-patterns onto a solid surface has gotten a lot of interest. Many organic molecules and nanomaterials have been anchored to gold surfaces via sulfur (disulfide, thiol, or thioether) groups or siloxane linkages on quartz and glass surfaces. Both provide significant contact at interfaces, making the creation of well-defined self-assembled monolayers (SAMs) simple.

Carbon nanotubes (CNTs) have unique electrical, thermal, and mechanical properties, indicating a wide variety of uses in novel materials and nanotechnology. The development of novel CNT-containing nanocomposites or nano-hybrids with increased solubility or suspensions in liquids, as well as new functions, is made possible by an intermolecularly covalent or non-covalent interaction among CNTs and polymeric or organic species (Sawhney et al., 2008). For example, oxidized CNTs have been widely employed to bond with polyelectrolytes or proteins to create new hybrid materials that combine the activities of both CNTs and polyelectrolytes or proteins. These oxidized CNTs can also react with protein amino substituents to generate CNT-protein nanocomposites.

According to the approach of You et al., oxidized multi-walled CNTs (MWNTs) were treated with S-(2-aminoethylthio)-2-thiopyridine hydrochloride to produce pyridylthio-modified MWNT (pythio-MWNT) nano-hybrids. These pythio-MWNTs are thought to have the following properties: (i) enhanced solubility in organic solvents; (ii) possible reaction with proteins via the S-S bond, with the exception of adsorption on the surface of pythio-MWNTs; and (iii) the ability to build SAMs on the gold electrode surface via the Au-S bond.

Moore's Law

Moore's rule states that the number of transistors per silicon chip doubles every year, as predicted by American engineer Gordon Moore in 1965. Moore was invited to provide predictions for the next 10 years for a special issue of the journal Electronics. He recklessly extended this annual doubling to the next decade, projecting that microcircuit in 1975 would include an incredible 65,000 components per chip, after observing that the overall number of components in these circuits had about quadrupled each year. Moore altered his time frame to two years in 1975, as the rate of expansion began to decline. His updated formula was a little pessimistic; the number of transistors increased every 18 months for the next 50 years starting in 1961. Moore's law was then referred to in publications as if it were inexorable—a technological law backed by Newton's laws of motion.

The continually diminishing size of transistors throughout the decades enabled this remarkable increase in circuit complexity. The dimensions of a typical transistor were measured in millimeters in the late 1940s, but in the early 2010s, they were more typically represented in tens of NMs (a NM is 1 billionth of a meter)—a reduction factor of over 100,000. In the 1980s, when dynamic random-access memory (DRAM) chips began delivering megabyte storage capacities, transistor features measuring less than a micron (a micrometer, or 1-millionth of a meter) were achieved (Figure 29).

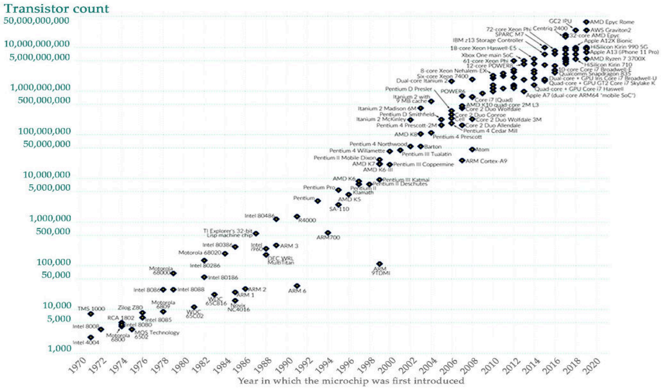


Figure 29. The exponential benefits of Moore's law are being slowed as semiconductor process technology evolves to molecular limits.

Source: https://everything-everywhere.com/moores-law/.

These characteristics were as small as 0.1 micron at the turn of the century, allowing the production of gigabyte memory chips and microprocessors with gigahertz frequencies. Moore's law was extended into the second decade of the 21st century with the emergence of tens of NM-sized three-dimensional transistors.

The complexity of semiconductor process technologies has always risen. Moore's law has been fueled by this phenomenon, which has been dubbed the "innovation engine." The rise in complexity has accelerated in recent years. Transistors are now three-dimensional electronics that behave in unexpected ways. Advanced process technologies' incredibly small feature sizes necessitate numerous exposures (multi-patterning) to precisely recreate these features on a silicon wafer. The design process has become significantly more complicated as a result of this (Sahoo and Labhasetwar, 2003).

Moore's law has been delayed as a result of all this intricacy. Moving to a new process node is still an option, but the high cost and difficulty of doing so has delayed migration. Furthermore, each new manufacturing node currently produces less significant density, efficiency, and power reduction results.

Macromolecule

A macromolecule, such as a protein, is a very large molecule. They are made up of thousands of atoms that are covalently bound. Many macromolecules are polymers of monomers, which are simpler molecules. Biopolymers (nucleic acids, proteins, and carbohydrates) and big non-polymeric molecules like lipids and macrocycles are the most prevalent macromolecules in biochemistry. Macromolecules include synthetic fibers and unconventional materials such as CNTs.

In many circumstances, particularly for synthetic polymers, a molecule can be said to have a high relative molecular mass if changing one or a few of the units has no influence on the molecular properties. This statement is false for some macromolecules, whose behaviors are highly dependent on molecular structure fine details. If a portion or the entirety of a molecule meets this criterion, it can be classified as macromolecular or polymeric, or by the adjectival term polymer (Safari and Zarnegar, 2014).

The term "large molecules" is used differently across fields. While macromolecules are defined in biology as the four massive molecules that make up living things, the term can also apply to aggregates of two or more molecules bound together by intermolecular interactions rather than covalent bonds and that do not quickly dissolve in chemistry. The term macromolecule as used in polymer science refers to a single molecule, according to the conventional IUPAC definition. For example, rather than a "polymer," which implies a substance made up of macromolecules, a single polymeric molecule is suitably referred to as a "macromolecule" or "polymer molecule."

Macrophages are difficult to explain solely in terms of stoichiometry due to their large size. The individual monomer subunit and total molecular mass can be used to characterize the structure of simple macromolecules like homopolymers. Complex biomacromolecules, on the other hand, necessitate a multifaceted structural description, such as the protein hierarchy. "High polymer" is a term used in British English to refer to macromolecules.

The physical properties of macromolecules are frequently exceptional in comparison to smaller molecules. Another typical macromolecular trait that does not apply to smaller molecules is their relative insolubility in water and other solvents, which causes colloids to develop. To dissolve in water, many require salts or specific ions. Similarly, if the solute concentration in a solution is too high or too low, many proteins will denature. Through a phenomenon known as macromolecular crowding, high concentrations of macromolecules in a solution can change the speeds and equilibrium constants of other macromolecule processes (Ravichandran, 2010). This is due to macromolecules obstructing other molecules from occupying a considerable portion of the solution's volume, resulting in higher effective concentrations of these molecules.

Synthetic polymers (plastics, fibers, and rubber), graphene, and CNTs are all instances of macromolecules. Polymers can be made from inorganic substances and used in inorganic polymers and geopolymers, for example. As seen in smart inorganic polymers, the addition of inorganic materials allows for the tuning of characteristics and/or responsive behavior.

Magnetism

Magnetic fields mediate a class of physical properties known as magnetism. A magnetic field is created by electric currents and the magnetic moments of elementary particles, which operates on other currents and magnetic moments. Electromagnetism is a multifaceted phenomenon that includes magnetism. The most well-known effects occur in ferromagnetic materials, which are highly attracted to magnetic fields and can be magnetized to become permanent magnets that generate magnetic fields. It is also feasible to demagnetize a magnet. Iron, cobalt, and nickel, as well as their alloys, are the most prevalent ferromagnetic materials. Neodymium and samarium, both rare-earth elements, are fewer common instances. Because permanent magnetism was first found in lodestone, a type of natural iron ore termed magnetite, Fe_3O_4, the prefix ferro-alludes to iron.

The bulk susceptibility of magnetic materials is used to classify them. Although ferromagnetism is accountable for the majority of magnetism's effects in everyday life, there are numerous types of magnetism. Paramagnetic materials, like aluminum and oxygen, are weakly driven to a magnetic field; diamagnetic materials, like copper and carbon, are poorly repelled; and antiferromagnetic materials, like chromium and spin glasses, have a more complicated connection with a magnetic field (Figure 30).

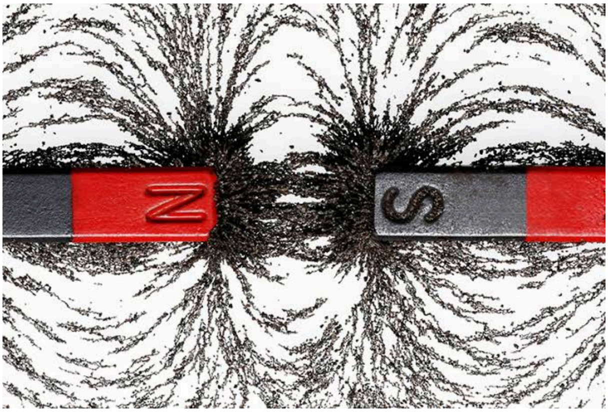


Figure 30. Magnetism exists in all substances in some form.

Source: https://www.accessscience.com/content/magnetism/398800.

Because the force of a magnet on diamagnetic, paramagnetic, and antiferromagnetic materials is usually too faint to be felt and can only be measured by laboratory instruments, these compounds are commonly referred to as non-magnetic in ordinary life. Temperature, pressure, and the induced magnetic field all influence a material's magnetic state (or magnetic phase). As these variables alter, a material may exhibit multiple forms of magnetism. Although the exact mathematical connection between strength and distance varies, the intensity of a magnetic field almost always declines with distance. Complicated magnetic fields can originate from various arrangements of magnetic moments and electric currents. Although some theories anticipate the presence of magnetic monopoles, only magnetic dipoles have been confirmed (Presting and König, 2003.

People originally noticed that lodestones, naturally magnetic bits of the mineral magnetite, could attract iron in the ancient world, and this led to the discovery of magnetism. The word magnet is derived from the Greek term o magntis lithos, which means "the Magnesian stone, lodestone." Aristotle credited the first academic debate of magnetism to the philosopher Thales of Miletus, who lived from approximately 625 BC to about 545 BC in ancient Greece. The Sushruta Samhita, an ancient Indian medicinal treatise, recommends utilizing magnetite to remove arrows buried in a person's flesh.

The earliest literary mention of magnetism in ancient China is found in a 4th-century BC work called after its author, Guiguzi. "The lodestone makes iron approach; some (force) is attracting it," Lüshi Chunqiu writes in the 2nd century BC chronicles. A lodestone draws a needle, according to a 1st-century text called Lunheng (Balanced Inquiries): "A lodestone attracts a needle." Shen Kuo, a Chinese scientist from the 11th century, was the first to write about the magnetic needle compass in the Dream Pool Essays, claiming that it enhanced navigation accuracy by using the astronomical idea of true north. The Chinese were known to employ the lodestone compass for navigation by the 12th century. They carved a directional spoon out of lodestone with the handle always pointing south.

By 1187, Alexander Neckam had described the compass and its application for navigation for the first time in Europe. The Epistola de magnete, the first existing book discussing the properties of magnets, was written by Peter Peregrinus de Maricourt in 1269. Al-Ashraf Umar II, a Yemeni scientist, astronomer, and geographer, discussed the properties of magnets and dry compasses in 1282.

A comprehension of the relation between electricity and magnetism originated in 1819, when Hans Christian Orsted, a professor at the University of Copenhagen, realized that an electric current could generate a magnetic field by accidentally twitching a compass needle near a wire. Orsted's experiment is the name of this seminal experiment (Porter et al., 2008).

James Clerk Maxwell combined electricity, magnetism, and optics into the field of electromagnetism by synthesizing and expanding these ideas into Maxwell's equations. Albert Einstein utilized these rules to motivate his special relativity theory in 1905, demanding that the laws hold true in all inertial reference frames. In the 21st century, electromagnetism has been included into more fundamental theories such as gauge theory, quantum electrodynamics, electroweak theory, and ultimately the standard model.

Mass Spectrometer

If you apply a sideways force to something moving, it will curve instead of going in a straight line, as the sideways forces deflect it from its initial course. Assume you are in the path of a cannonball, and you wish to divert it. All you have is a hose-pipe full of water that you may squirt at it. It will not make a significant difference! Because the cannonball is so heavy, it will only be slightly deflected from its intended path. But what if you used the same jet of water to deflect a table tennis ball traveling at the same speed as the cannonball? Because this ball is so light, it will deflect a lot.

The amount of deflection for a given sideways force is determined by the ball's mass. If you knew the ball's speed and the magnitude of the force, you could figure out how much mass it had if you knew what kind of curved path it was deflected through. The ball will be heavier if there is less deflection. The same technique can be applied to atomic-sized particles.

Chemical substances are detected via mass spectrometry, also known as mass spectroscopy, which involves sorting gaseous ions in electric and magnetic fields as per their mass-to-charge ratios. Mass spectrometers and mass spectrographs are the equipment utilized in this research, and they work on the idea that moving ions can be deflected by electric and magnetic fields. The sole difference between the two instruments is how the sorted charged particles are detected (Patil et al., (2008).

They are recognized electrically in the mass spectrometer and by photographic or other nonelectrical means in the mass spectrograph; the word mass spectroscope is used to refer to both types of equipment. Due to the widespread use of electrical detectors, the field is now known as mass spectrometry.

Both qualitative and quantitative applications are possible with mass spectrometry. Unknown compounds can be identified, the isotopic makeup of elements in a molecule can be determined, and the structure of a compound can be determined by observing its fragmentation. Quantifying the quantity of a molecule in a sample or studying the foundations of gas phase ion chemistry are two more applications (the chemistry of ions and neutrals in a vacuum). MS is currently widely employed in analytical laboratories for investigating the physical, chemical, and biological properties of a wide range of substances (Figure 31).

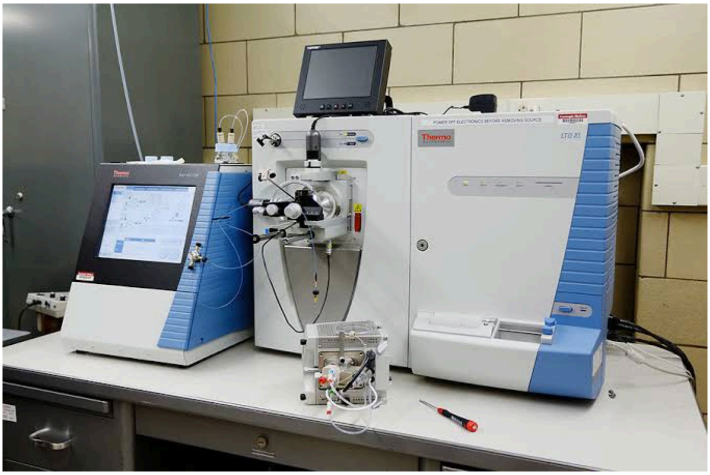


Figure 31. Chemical substances are detected via mass spectrometry, also known as mass spectroscopy.

Source: https://www.cmu.edu/chemistry/facilities/cma/instruments/mass_spec.html.

It has significant advantages as an analytical tool, including increased sensitivity above most other analytical techniques since the analyzer minimizes background interference as a mass-charge filter; To identify unknowns or confirm the existence of suspected substances, distinctive fragmentation patterns provide excellent specificity. Chemical data with a temporally resolved molecular weight, isotopic abundance of elements, and chemical data with a temporally resolved molecular weight. One of the method's drawbacks is that it frequently fails to discriminate between optical and geometrical isomers, as well as substituent locations in the o-, m-, and p-positions in an aromatic ring. Its ability to identify hydrocarbons that create identical fragmented ions is also limited.

Micro-Contact Printing

Micro-contact printing is a technique for transferring patterns of polymers, proteins, nanoparticles, and other materials onto another surface. A polydimethylsiloxane (PDMS) stamp is typically dipped in a solution of the substance to be patterned before being applied to the surface. This approach allows for the transfer of micrometer (m)/nanometer (nm) scale patterns. For ages, both lithography and stamp printing have existed. The combination of the two, however, gave rise to the micro-contact printing technology. At Harvard University, George M. Whitesides and Amit Kumar were the first to introduce the approach. Many methods of soft lithography have been investigated since its inception (Baruah and Dutta, 2009).

Micro-contact printing has a number of advantages, including the ease with which designs with micro-scale details can be created; Can be performed in a typical laboratory without the use of a cleanroom on a regular basis (the cleanroom is only required to build the master); A single master can be used to make several stamps. Individual stamps can be utilized multiple times with negligible performance impact; A less expensive fabrication approach that consumes less energy than traditional methods; and Other micropatterning methods are not available for some materials.

There are however some limitations. Direct contact with the stamp should be avoided because it can easily be physically distorted, resulting in printed features that differ from the original stamp features. The raised and recessed characteristics will distort if the stamp is stretched or compressed horizontally. During printing, too much vertical pressure on the stamp might cause the raised relief features to flatten on the substrate. Even though the initial stamp has a lower resolution, these deformations can give sub-micron details.

The stamp can deform during the removal process from the master as well as during the substrate contracting process. Buckling of the stamp can occur when the aspect ratio is too high. Roof collapse can occur when the aspect ratio is too low. Some pieces may remain uncured during the curing process, contaminating the process. The quality of the printed SAM suffers as a result of this. The transmission of these contaminants is exacerbated when the ink molecules contain particular polar groups.

The stamp may reduce in size during the curing process, resulting in a change in the substrate patterning's desired dimensions. It is possible that the stamp will swell. Most organic solvents cause the PDMS stamp to bulge. Although ethanol has a low swelling impact, several other solvents cannot be utilized for wet inking due to their significant swelling. As a result, the method is confined to polyamide inks that are ethanol-soluble (Pathakoti et al., 2018).

During the development of the patterned SAM on the substrate, ink diffuses from the PDMS bulk to the surface. The ink's mobility can induce lateral spread to undesirable areas. This spreading can alter the desired pattern during the transfer.

The micro-contact printing process has a wide range of uses depending on the type of ink used and the following substrate. In micro-machining, micro-contact printing offers a lot of potential. A solution of alkanethiol is often used in inking solutions for this use. Metal substrates are used in this process, with gold being the most prevalent metal. Silver, copper, and palladium, on the other hand, have been shown to work. The SAM layer works as a resist to standard wet etching procedures, allowing for high resolution patterning once the ink has been deposited to the substrate (Nikalje, 2015). The patterned SAMs layer is one of several steps in the process of creating complex microstructures. Applying the SAM layer on top of gold and etching it creates gold microstructures, for example. Following this stage, etched gold portions reveal the substrate, which can then be etched using typical anisotropic etch techniques. These stages can be completed without the need of standard photolithography thanks to the micro-contact printing technique.

Biosensors, cell biology studies, and tissue engineering have all benefited from protein patterning. Various proteins have been proved to be appropriate inks for micro-contact printing and are applied to a variety of substrates. Glass, polystyrene, and hydrophobic silicon have all been effectively coated with polylysine, IgG antibody, and other enzymes.

Micro-contact printing has been utilized to learn more about how cells interact with their surroundings. This approach has made it possible to examine cell patterning in ways that traditional cell culture techniques could not. This method has also been used to successfully pattern DNA. The advantages of utilizing this technology are the savings in time and DNA material. The stamps were more uniform and sensitive than other procedures and could be used several times.

Micro-Molding

Micro-molding is a highly specialized field of expertise. It is a type of injection molding that involves creating a cavity to match the shape of the object you want to produce, similar to how Lego bricks are made with plastic molding.

The term “micro” refers to the component’s size. When it comes to micro-molding, this is the most typical definition. The term “microfeatures” refers to little elements on a bigger part. The part as a whole may be large, but its components, or micro characteristics, may be miniscule (Bohr, 2002). Micro intolerance refers to how parts are measured and how close they must be to the required measurement to be regarded excellent or useful. When a part is molded, it must fit within the required tolerance, which could be as small as 1000th of an inch. Small pieces that are simple to create have looser tolerances and are referred to as ordinary molding (Figure 32).

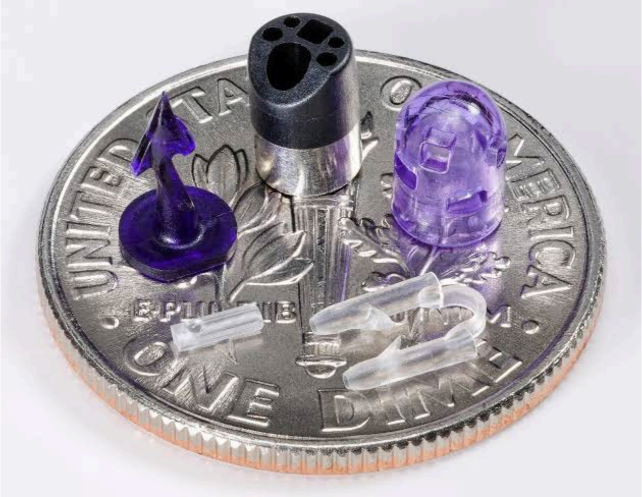


Figure 32. MTD's unique skills in discovering and making very small, delicate, and complicated components are needed for sophisticated medical applications and items such as specialty procedures, bioabsorbable devices, and implant devices are available.

Source: https://www.meddeviceonline.com/doc/medical-micromolding-0003.

PEEK, PEI, liquid crystal polymer, and nylon are some of the typical thermoplastic moldable materials used in micro-molding. Durometer or elastomeric materials can also be used in some micro-molding pieces. For medical device parts, they can also be manufactured of optical-grade and medical-grade materials. Molds can be as small as the size of a dime thanks to the materials utilized. A runner system is used to transport plastic from its melting point to the cavity where it is formed into the appropriate shape. In other circumstances, the runner might be quite long, and that extra room is required to get the plastic where it has to go. The runner system's size in relation to the part's size is waste. You do not want to make a small portion with a lot of waste, according to Johnson. In terms of part size and runner system, true micro molding is efficient (Bhattacharyya et al., 2009).

Some firms have micro-molding sizes as small as 800-by-300-by-380 microns, while others have micro-molding sizes as high as half an inch.

According to Accumold, micro-molded parts can have a part volume of 0.005 cubic inches or less. Building micro-parts necessitates a high level of attention to detail and experience. While producing a small part can be difficult, the parts can be straightforward to construct if the company is able to manufacture high-precision parts. Each company's micro-molding method is unique.

MOCVD (Metal-Organic Chemical Vapor Deposition)

This is a method of producing single- or polycrystalline thin films using chemical vapor deposition (CVD). It is a method for creating sophisticated semiconductor multilayer structures by developing crystalline layers. Unlike molecular-beam epitaxy (MBE), crystal development is based on chemical reactions rather than physical deposition. This occurs at modest pressures in the gas phase, rather than in vacuum (10 to 760 Torr). As a result, this method is favored for the fabrication of devices using thermodynamically metastable alloys, and it has become a key step in the production of optoelectronics like light-emitting diodes (LEDs).

MOCVD involves injecting ultra-pure precursor gases into a reactor, generally with a non-reactive carrier gas. A metalorganic could be utilized as the group III precursor and a hydride as the group V precursor in a III-V semiconductor. Trimethylindium $(CH_3)3In$ and phosphine (PH_3) precursors, for example, can be used to generate indium phosphide.

The precursors undergo pyrolysis when they approach the semiconductor wafer, and the products adsorb onto the semiconductor wafer surface. The elements are incorporated into a new epitaxial layer of the semiconductor crystal lattice as a result of the surface reaction of the precursor material. Supersaturation of chemical species in the vapor phase drives growth in the mass-transport-limited growth regime that MOCVD reactors typically operate in. MOCVD may produce films having group III and group V, group II and group VI, and group IV combinations.

The required pyrolysis temperature rises as the chemical bond strength of the precursor increases. The weaker the connection becomes as more carbon atoms are connected to the core metal atom. Atomic steps on the surface influence atom diffusion on the substrate surface. Because it influences the growth rate in the mass-transport-limited phase, the vapor pressure of the group III metal-organic source is an important control parameter for MOCVD growth (Bowman and Hodge, 2007).

The metal-organic chemical vapor deposition (MOCVD) process involves combining reactant gases in a reactor at high temperatures to create a chemical reaction that results in the deposition of components on the substrate. A reactor is a chamber built of a substance that does not react with the chemicals. It must also be able to tolerate extreme temperatures. The reactor walls, liner, susceptor, gas injection units, and temperature control units make up this chamber. The reactor walls are often constructed of stainless steel or quartz.

The liner in the reactor chamber between the reactor wall and the susceptor is frequently made of ceramic or specific glassware, such as quartz. Cooling water must flow through the passages within the reactor walls to prevent overheating. A substrate is placed on a temperature-controlled susceptor. The susceptor is usually constructed of graphite, which is resistant to the metal-organic compounds utilized. To grow nitrides and related materials, a specific coating on the graphite susceptor, commonly silicon nitride, is required to avoid ammonia (NH_3) gas corrosion.

A cold-wall reactor is one form of reactor used in MOCVD. The substrate in a cold-wall reactor is supported by a pedestal that also serves as a susceptor. In the reaction chamber, the pedestal/susceptor is the principal source of heat energy. Gases do not react before reaching the hot wafer surface because only the susceptor is heated. A radiation-absorbing substance, such as carbon, is used for the pedestal/susceptor. In a cold-wall reactor, on the other hand, the reaction chamber walls are commonly composed of quartz, which is largely transparent to electromagnetic radiation (Contreras et al., 2017).

In a cold-wall reactor, however, heat radiating from the hot pedestal/susceptor may indirectly heat the reaction chamber walls, but they will remain colder than the pedestal/susceptor and the substrate it supports. The entire chamber is heated in hot-wall CVD. Some gases may need to be pre-cracked before reaching the semiconductor surface in order for them to adhere to the wafer.

‘Bubblers’ are devices that are used to introduce gas. A carrier gas (typically hydrogen in arsenide and phosphide growth, or nitrogen in nitride growth) is bubbled through the metalorganic liquid in a bubbler, picking up some metalorganic vapor and transporting it to the reactor. The amount of metalorganic vapor carried is determined by the rate of carrier gas flow and the temperature of the bubbler and is typically controlled automatically and with the greatest precision by an ultrasonic concentration measuring feedback gas control system. Saturated vapors must be considered.

Molecular Beam Epitaxy

The epitaxy method MBE is used to deposit thin films of single crystals. MBE is a crucial technique for the development of nanotechnologies and is widely employed in the fabrication of semiconductor devices, including transistors. MBE is used to make microwave-frequency diodes and MOSFETs (MOS field-effect transistors), as well as lasers for reading optical discs (such as CDs and DVDs).

Günther was the one who first proposed the MBE process. He did not deposit epitaxial films, but rather films on glass substrates. Davey and Pankey used Günther's approach to grow GaAs epitaxial films on single-crystal GaAs substrates, demonstrating the MBE process with the development of vacuum technology. J.R. Arthur's studies on kinetic behavior of growth processes and Alfred Y. Cho's in situ observation of the MBE process utilizing RHEED in the late 1960s paved the way for the subsequent development of MBE films (Chauhan et al., 2012).

RHEED (reflection high-energy electron diffraction) is frequently used to monitor the formation of crystal layers during operation. Shutters in front of each furnace are controlled by a computer, allowing precise control of layer thickness down to a single atom layer. This method can be used to create intricate constructions made up of layers of various materials. The development of structures where electrons can be confined in space, such as quantum wells or quantum dots (QDs), has been enabled by this control.

The ultra-high vacuum atmosphere within the growth chamber is sustained by a series of cryopumps and cryopanels, cooled using liquid nitrogen or cold nitrogen gas to a temperature close to 77 kelvins (196°C) in systems where the substrate must be cooled. Because contaminants in the vacuum sink to cold surfaces, vacuum levels must be several orders of magnitude higher to deposit films under these conditions. In alternative techniques, the wafers on which the crystals are formed may be put on a revolving platter, which can be heated to several 100°C during operation.

Some forms of organic semiconductors are also deposited using MBE. Instead of atoms, molecules are evaporated and deposited onto the wafer in this scenario. Gas-source MBE, which resembles CVD, is another type. MBE systems can also be customized to meet specific requirements (Chen and Yada, 2011). For example, oxygen sources can be used to deposit oxide materials for advanced electronic, electromagnetic, and optic applications, as well as for basic research (Figure 33).

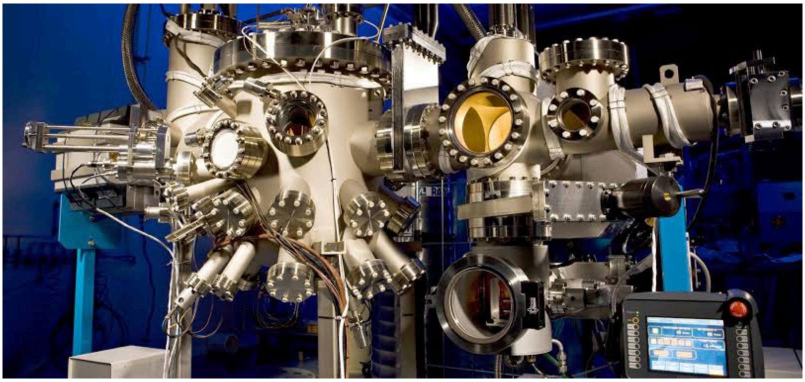


Figure 33. Many modern semiconductor devices, such as semiconductor lasers and light-emitting diodes, now require such layers.

Source: https://www.riber.com/.

The nanostructures that allowed the construction of atomically flat and abrupt hetero-interfaces are one of the most successful feats of MBE. Such structures have aided in the advancement of physics and electronics understanding in new ways. Most recently, the development of nanowires and quantum structures within them, which enable information processing and integration with on-chip quantum communication and computer applications. Only advanced MBE techniques, which allow monolithic integration on silicon and picosecond signal processing, can be used to construct these heterostructure nanowire lasers.

Molecular Imprinting

Molecular imprinting is a method for making template-shaped cavities in polymer matrices with high affinity and selectivity. This method is based on the "lock and key" paradigm of substrate recognition utilized by enzymes. An enzyme's active binding site has a form that is particular to a substrate. Alternative shapes that do not fit the binding site are not recognized, whereas substrates with a complementary shape to the binding site selectively bind to the enzyme (Doubleday, 2007).

A template molecule and functioning monomers that gather around the template and then cross-link to each other are used to create molecularly imprinted materials. The monomers are polymerized to form an imprinted matrix (also known as a molecular imprinted polymer (MIP) that self-assembles around the template molecule due to interactions between functional groups on both the template and the monomers. The template is then partially or completely removed, leaving behind a cavity that is similar in size and shape to the template. For the templated molecule, the cavity created can serve as a selective binding site.

The molecular imprinting technology has been developed in recent decades for use in the delivery of drugs, separations, biologic, and biochemical sensing, and other applications. Able to take advantage of the cavity's shape selectivity, application in catalysis for certain reactions has also been made easier (Ehdaie, 2007).

M.V. Polyakov's experiments on the polymerization of sodium silicate with ammonium carbonate in 1931 are credited as the earliest example of molecular imprinting. The resultant silica demonstrated a greater uptake of the additive when the polymerization process was supplemented by an additive such as benzene. Dickey applied the instructional theory molecular imprinting notion in 1949; his research precipitated silica gels in the presence of organic dyes and demonstrated that imprinted silica had excellent selectivity towards the template dye.

Wulff and Klotz first applied molecular imprinting to organic polymers in 1972. They discovered that covalently introducing functional groups into the imprinted cavity of polymers allowed for molecular recognition. The Mosbach group then demonstrated that non-covalent interactions may be used to inject functional groups into imprinted cavities, resulting in non-covalent imprinting. Many molecular imprinting techniques have since been applied to a variety of applications.

Affinity-based separations for biomedical, ecological, and food monitoring are one application of molecular imprinting technology. MIPs can be used to remove selected trace quantities of analytes from samples, allowing for sample preconcentration and treatment. Several studies have looked into the feasibility of MIPs in solid-phase extraction, solid-phase micro-extraction, and stir bar sorption extraction (Farokhzad and Langer, 2009). MIPs can also be used as packing materials and stationary phases in chromatography techniques like HPLC and TLC to separate template analytes. Because the kinetics of noncovalently imprinted materials are faster than those of covalently imprinted materials, noncovalent MIPs are more widely used in chromatography.

The use of molecularly imprinted materials as chemical and biological sensors is another application. Herbicides, sweets, medicines, poisons, and vapors are all targets for them. MIP-based sensors feature great selectivity and sensitivity, as well as the ability to generate detecting signals (electrochemical, optical, or piezoelectric). They can be used in fluorescence sensing, electrochemical sensing, chemiluminescence sensing, and UV-Vis sensing as a result of this. Detecting illicit substances, banned sports drugs, poisons, and chemical warfare chemicals is another area of significant interest in forensic applications.

In domains like medicine delivery and biotechnology, molecular imprinting has been progressively gaining traction. Artificial antibodies can be made using the selective interaction between template and polymer matrix. MIP adsorbents can be used to separate amino acids, chiral chemicals, hemoglobin, and hormones in the biopharmaceutical business. It has been investigated how to use molecular imprinting techniques to simulate linear and polyanionic molecules such as DNA, proteins, and carbohydrates. Protein imprinting is a difficult area (Gupta, 2011).

Because their structural integrity cannot be guaranteed in synthetic contexts, large, water-soluble biological macromolecules have provided a challenge for molecular imprinting. Immobilizing template molecules at the surface of solid substrates, hence limiting aggregation, and commanding template molecules to locate at the surface of imprinted materials are two current ways for navigating this. However, a thorough study of molecular imprinting of proteins by Utrecht University scientists indicated that more testing is needed.

MIPs' stable conformations, quick equilibrium release, and resistance to enzymatic and chemical stress are used in pharmaceutical applications such as selective drug delivery and control drug release systems. The release of a therapeutic substance as a result of a specific stimulus, known as intelligent drug release, has also been investigated (Gunasekaran et al., 2014). At the nanoscale, molecularly imprinted insulin and other therapeutic materials were discovered to have a high adsorption capacity for their respective targets, indicating a tremendous potential for new drug delivery methods.

Monomer

A molecule that can polymerize, hence contributing constitutional units to a macromolecule's important component. Monomers can be categorized in a variety of ways. Depending on the type of polymer they produce, they can be split into two categories. The stoichiometry of monomers that engage in condensation polymerization differs from monomers that engage in addition polymerization.

A homopolymer is formed when one kind of monomer is polymerized. Many polymers are copolymers, which means they are made up of two monomers. The ratio of comonomers in condensation polymerizations is typically 1:1. Many nylons, for example, require equal amounts of dicarboxylic acid and diamine to be formed. The comonomer content of addition polymerizations is typically only a few percent. To make specialized polyethylene, small amounts of 1-octene monomer are copolymerized with ethylene (Huang et al., 2010).

Monomers with a double bond between two atoms or a ring of three to seven atoms are known to undergo addition reactions; examples include styrene, caprolactam (which makes nylon 6), butadiene, and acrylonitrile (which copolymerize to form nitrile rubber, or Buna N). Condensation polymerizations are common in monomers having two or more reactive atomic groups; for example, a chemical that is both an alcohol and an acid can create a long-chain polyester by repeatedly estering the alcohol group of each molecule with the acid group of the next.

Microtechnology

Microtechnology is concerned with technology having features on the order of one micrometer (1 millionth of a meter, or 106 meters, or 1 meter). It focuses on physical and chemical processes, as well as the creation and manipulation of one-micrometer structures.

Around 1970, scientists discovered that by arranging a large number of microscopic transistors on a single chip, they could create microelectronic circuits with vastly better performance, functionality, and reliability while lowering costs and increasing volume. The Information Revolution arose as a result of this progress. Scientists have lately discovered that not just electrical devices, but also mechanical devices, maybe downsized and batch-fabricated, giving the mechanical world the same benefits that integrated circuit technology has provided to the electrical world (Kandel et al., 2013).

While electronics now offer the ‘brains’ for today’s modern systems and goods, micromechanical devices can supply the sensors and actuators that connect with the outside world — the eyes, ears, hands, and feet. Micromechanical devices are now used in a variety of goods, including car airbags, ink-jet printers, blood pressure monitors, and projection display systems. It appears that these devices will become as common as electronics in the not-too-distant future. The method has also gotten more accurate, reducing the technology's size to the sub-micrometer range, as evidenced by sophisticated micro-electric circuits with dimensions of less than 20 nm.

Micro Electromechanical Systems, or MEMS, is a word that was coined in the 1980s to describe new, sophisticated mechanical systems on a chip, such as micro electric motors, resonators, gears, and so on. In reality, the term MEMS now refers to any microscopic device with a mechanical function that can be manufactured in a batch process.

MEMS are simply referred to as "micromachines" in Japan, and MST for Micro System Technology is favored in Europe. The differences between these names are slight, and they are frequently used interchangeably. Though there are thousands of various MEMS techniques, they are commonly categorized into a few categories, such as surface machining, bulk machining, LIGA, and EFAB. Some have simple 3-D geometry, while others have more complicated 3-D geometries and greater versatility.

To make an accelerometer for inertial navigation, a business that makes airbag accelerometers would need a whole different design and method. Changing from an accelerometer to another inertial device like a gyroscope necessitates even more design and process changes, as well as a different production site and technical team (Kaur et al., 2014). Due to the wide number of essential applications where MEMS can provide previously unreachable performance and reliability criteria, MEMS technology has sparked a lot of interest.

MEMS provides a compelling answer in an age where everything must be smaller, faster, and cheaper. In some applications, such as automotive sensors and inkjet printers, MEMS have already had a significant influence. The MEMS business, which is still in its infancy, is now a multibillion-dollar enterprise. It is predicted to grow quickly and become a big industry in the 21st century. Photolithography is frequently used in the manufacture of microtechnology. Light waves are focused onto a surface through a mask. They make a chemical film solidify. The film's soft, unexposed areas are wiped away. The unprotected material is then etched away by acid.

The integrated circuit is microtechnology's most well-known success. Micromachinery has also been built with it. Nanotechnology originated in the 1980s as an offshoot of researchers aiming to further miniaturize microtechnology, notably following the advent of new microscope techniques. These resulted in materials and structures with dimensions ranging from 1–100 nm.

N

Nanocrystal

Nanocrystals are materials particles with at least one dimension being smaller than 100 nanometers. They are based on quantum dots (QDs) also known as nanoparticles and they contain atoms in with poly-crystalline or single arrangement. Nanocrystals are easily defined by their size. They are smaller in size compared to other naturally occurring crystals. Their size allows them to be used in various fields. For instance, silicon nanocrystals are used in providing efficient light emission, a function that cannot be achieved by using bulk crystals. They can also be used as memory components. There are times when nanocrystals are embedded in solids causing them to exhibit more complex melting behavior when compared to conventional solids (Kung and Kung, 2004). The resulting substance forms the basis of a special class of solids. Their behavior becomes like that of a single-domain systems. This is when the volume within the system has the same molecular and atomic arrangement throughout. This behavior is useful in explaining the behavior of macroscopic samples of a familiar material without looking into complex details such as the presence of grain boundaries, among other defects. QDs are used to describe semiconductor nanocrystals with dimensions smaller than 10 nm. There are various methods of synthesizing nanocrystals. The traditional techniques made use of molecular precursors. They include typical metal salts as well as the anion source. A significant number of semiconducting nanomaterials have nuclides and chalcogenides. Silylated derivatives like triaphosphine and bissulfide are sources of nanocrystals. Some production methods use surfactants in solubilizing the growing nanocrystals. There are other cases where through atomic diffusion, the nanocrystals exchange their elements with reagents. There are various applications of nanocrystals among them include their use in filters where zeolite nanocrystals are used in filtering crude oil into diesel fuel. This is the case at a Louisiana's ExxonMobil oil refinery. This method is said to be much cheaper compared to other conventional methods. It is also used in wear resistance. The level of hardness of nanocrystals is almost similar to that of optimized molecular hardness. This is a very useful element in the wear resistance industry.

Nanocomputer

A nanocomputer is a computer very small in size. It is smaller than the microcomputer which is in turn smaller than the minicomputer. Semiconductor transistors are used in microelectronic components. The microelectronic components are part of the core of all modern electronic devices. Computing devices whose size can be compared to that of a credit card are referred to as a nanocomputer. Among the various types of nanocomputers is the modern single-board computers. Gumstix and Raspberry can be classified as nanocomputers. It can also be argued that tablets and smartphones can fall under this category. Over the years in the computing world, the goal has been to reduce the size of transistors on silicon microprocessors. This goal is not far from being achieved as several technologies have been developed to increase the speed and also the miniaturization process. In nanocomputers, the silicon transistors have been replaced with transistors based on CNTs. A carbon nanotube is defined as a molecule that takes the form of a hollow cylinder with a diameter close to a nanometer containing pure carbon (Klimeck et al., 2008). Among the recent technologies in display techniques is nanorods. The technology is advantageous as they consume less amount of electricity and they emit less heat. Micro processor's size has over the years reduced in size and are currently very small in size. Nanodots are the growing arrays of magnetic nanoparticles. There are different types of nanocomputers, namely quantum nanocomputers, biochemical nanocomputers, electric nanocomputers and mechanical nanocomputers. In the case of mechanical nanocomputers, the first of its kind was designed in 1837 by Charles Babbage. It was called the difference engine No. 1. The proposed design of mechanical nanocomputers was based on gears and rods made of molecules. For electronic nanocomputers, they are used in devices whose information is represented as electrostatic charge which is the charge of a single electron. Electrostatic charge is both a scalar quantity and a magnitude. It also makes use of elementary components that are based on soft materials such as CNTs, semiconducting polymers, and organic molecules rather than inorganic solid-state materials. For a chemical nanocomputer, computation is done on the basis of chemical reactions, which involves the formation and breaking of bonds. For the reactants, the inputs are encoded into the molecular structure and after the reaction, the output is extracted from the structure of the products. DNA computing was proposed on 1994. It was explained that the spiraling molecule (DNA) carries life's genetic code and can be used in conducting computations. The final type of nanocomputers is the quantum nanocomputers and they work by storing data in the form of atomic quantum spin or states. The technology has not been fully developed. It is still at the developing state as a single electron memory and QDs.

Nanoelectronics

The term nanoelectronics is used when electrical components use nanotechnology. The term can be used to cover different materials and devices. The common properties are that they exhibit small inter-atomic interactions. A lot of research is still needed with quantum mechanical properties. Advanced molecular electronics, one-dimensional nanowires or nanotubes or semiconductor electronics can fall under this category. Nanoelectronic devices are known for their critical dimensions. Their size ranges from 1 nm to 100 NM. Though there are several technological advancements, high-technology production processes are done on the basis of traditional top-down strategies. There are small changes with the introduction of nanotechnology. Currently the length scale of integrated circuits (ICs) has been reduced to the nanoscale. This is applicable for the length of the gate in transistors such as DRAM or CPUs devices. There are various applications of nanoelectronics, the most common being in computers. It is speculated that nanoelectronics possesses the ability to make computer processes very powerful even more powerful than the conventional semiconductor fabrication techniques. There are various approaches under research including nanolithography (NL) and the use of nanomaterials like nanowires in replacing traditional CMOS components. A good example of technologies that have been developed using nanoelectronics is the field-effect transistor. They are made using heterostructured semiconductor nanowires and semiconducting CNTs.

Nanomachine

A nanite or a nanomachine is an electrical or mechanical device whose dimensions are measured in nanometers. Nanomachines have extensive applications though most of them are in the research and development phase. A few devices have been tested. A good example of such devices are the sensors with a switch approximately 1.5 nanometers across. Such kinds of sensors are able to count certain molecules in a chemical sample. Among the applications of nanomachines is in the medical field where medical technology is used in the identification of toxins and pathogens from samples of body fluids. Nanomachines are also used in the detection of toxic chemicals as well as the measurement of the level of concentrations of such chemicals in the environment (Lakhal and Wood, 2011). The high operational speed of nanomachines can be attributed to their microscopic size. It is said that it is a natural tendency of all machines and systems to work at a faster rate as their size reduces. The good thing about nanomachines is that they can be programmed to replicate. They can also construct nanochips or work synergistically in building large machines. Nanorobots are specialized nanomachines. This kind of nanomachine can be used in the diagnosis of diseases, treating of certain diseases, or checking form invading viruses or bacteria and when found, it can destroy them. Another benefit of nanomachines is that each unit requires a small amount of energy to operate. They are also relatively durable in that nanomachines can last for centuries before they stop working. Limitations in the use of nanomachines is in the manufacture whereby the method of production may present a challenge. Production and growth of nanomachines may resemble that of seeds growing to become plants.

Nanomanufacturing

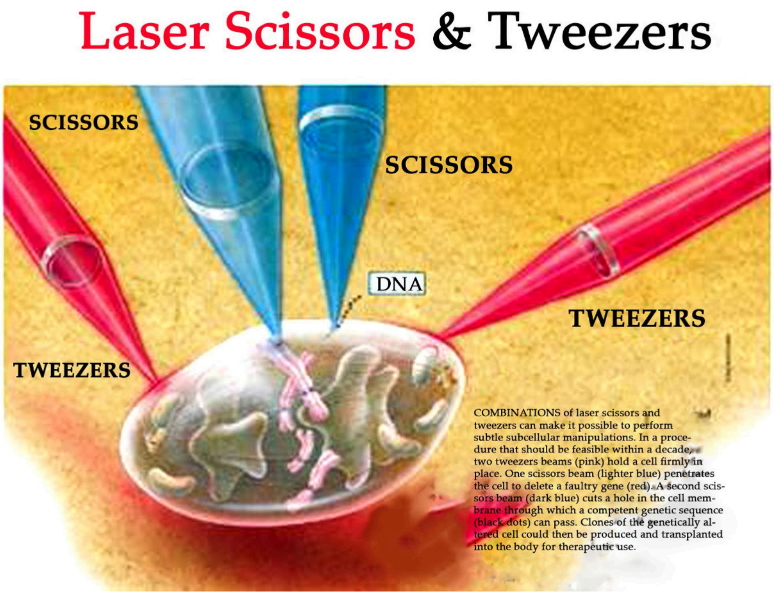
Nanomanufacturing is a type of manufacturing process involved in the production of nanoscale materials that can either be fluids or liquids. It is also used in the manufacture of parts top-down in small steps to ensure high levels of precision or bottom-up from nanoscaled materials. Nanomanufacturing is used in various technologies including etching and laser ablation, among others. Nanomanufacturing and molecular manufacturing are very different.

Molecular manufacturing is the manufacture of very complex nanoscale structures by using non-biological mechano-synthesis. There is extensive use of the term ‘nanomanufacturing.’ The National Nanotechnology Initiative in the U.S. and the European Technology Platform MINAM use this term. The NNI is a sub-domain of nanotechnology. It is one of its five priority areas. A nanomanufacturing program was developed and used in the National Science Foundation in the U.S. This led to the establishment of the National Nanomanufacturing Network. The organization seeks to expedite the transition of nanotechnologies into product manufacturing from laboratory research. This is achieved through road map development, strategic workshop, and exchange of information. Nanotechnology is defined differently according to context. For instance, the NNI defines nanotechnology in a widely so that it incorporates a variety of tiny structures.

Nanosurgery

Nanosurgery is a type of surgery that makes use of fast laser beams focused by an objective microscope lens so as to exert a controlled force that can allow the manipulation of organelles and other subcellular structures. It is a precision technique. It enables the destruction of one cell without causing damages to adjacent cells. It also facilitates the precise ablation of both cellular and subcellular structures while ensuring that the cell’s viability is not compromised. It also ensures the least amount of damage to adjacent cells. In conventional nanosurgery, optical tweezers are used. The optical tweezers are made of beams of laser light. For a particular laser beam, the narrowest point contains strong electric field gradient at the center. The electric gradient attracts dielectric particles in that they move along the gradient towards the enabling particles that will be moved from one area to another (Lieber, 2003). One area of application for optical tweezers is in biological substructures like chromosomes and cell nuclei. There are cases where optical tweezers are used with a scalpel to provide a higher prevision during surgery. There are cases where ultrafast laser nanosurgery is used to provide a high flux of photons. The photons can be absorbed in a nonlinear manner by electrons. The absorption process occurs over a short period of time and it results in fast and efficient plasma generation at the focal point of the beam. This results in the provision of a few nanojoules for subcellular structure ablation. Any damages incurred due to this technology are dependent on the pulse intensity, repetition rate of the laser and the total number of pulses. However, the wavelength of the beam has low effects.

The density of free electrons influences the dissection effect on tissues (Figure 34).



COMBINATIONS of laser scissors and tweezers can make it possible to perform subtle subcellular manipulations. In a procedure that should be feasible within a decade, two tweezers beams (pink) hold a cell firmly in place. One scissors beam (lighter blue) penetrates the cell to delete a faulty gene (red). A second scissors beam (dark blue) cuts a hole in the cell membrane through which a competent genetic sequence (black dots) can pass. Clones of the genetically altered cell could then be produced and transplanted into the body for therapeutic use.

Figure 34. Optical trapping and nanotechnology surgery can be used to alter DNA makeup.

Source: https://www.frontiersin.org/research-topics/12133/optical-trapping-laser-tweezers-and-nanosurgery-laser-scissors.

Nanotechnology

The term nanotechnology is used to refer to the field of research and innovation involved in the building of objects or structures on the scale of atoms or molecules. Dimensions of structures or objects made under Nanotechnology are measured in nanometers. A nanometer is 1-billionth of a meter. When using the nanoscale, basic rules of chemistry and physics do not hold ground (are not applicable). For example, the characteristics of materials such as their reactivity, conductivity, strength, and color. This character may differ substantially between the nanoscale and macro. Structures or objects are built using materials known as nanomaterials. The CNTs are very strong compared to steel though they are very light. Currently, knowledge and demand for nanotechnology is on the rise as it is said to have the potential to improve the efficiency of energy consumption, solve health problems and help improve the state of the environment. The demand is very high in manufacturing industries are the offer reduced cost of production. The advantage with products of nanotechnology is that they are small, light, cheap, very functional, require fewer raw materials for manufacture and they require less energy. Due to the benefits presented by nanotechnology, the race is on to use its potential and make profits from it. It has been noted that several governments believe that nanotechnology will be useful in helping countries generate wealth and improve productivity. Some countries have made big investments in nanotechnology research projects. Other than helping improve the wealth and productivity of a country, nanotechnology can also be used in the medical field in facilitating the provision of cheaper and more reliable systems of drug delivery. For instance, nanoparticles can be used to provide encapsulation systems that will enable the protection and secretion of enclosed drugs at a slow and controlled manner. This could be the solution to countries and areas faced with the challenge of poor storage facilities and distribution networks. It will be beneficial for patients on complex drug regimens and are unable to travel long distances to get drugs at a given frequency.

Nanometer

The nanometer is a unit of measurement that equates to 1 billionth of a meter. This unit of measurement is mostly used in the field of nanotechnology when measuring objects in the nanoscale. As the nanoscale is very small, a nanometer is used as a scale for building tiny, complex, and atomic scales used in electronic components and in computing. A nanometer is used in the measurement of very small things more so those in the size of an atom of a molecule. Therefore, the term is used in the context of miniature computing devices. Examples of such devices are transistors embedded within a processor and ICs. Transistors on semiconductor-based processor have their sizes measured in nanometers. A microchip hanging transistors that are 100 nanometers wide are able to accommodate more than a billion transistors within each microchip die. Objects in the atomic scale have their dimensions expressed in nanometers (Lü et al., 2009). For instance, the diameter of a helium atom is about 0.06 nm while that of a ribosome is about 20 nm. The nanometer is usually used in specifying the wavelength of electromagnetic radiations that fall within the visible part of the spectrum. The wavelengths of visible light ranges from 400–700 nm. The nanometer has various applications regarding measurement. For instance, in the 1980s, the nanometer has been used in the 22 NM and the 32 NM semiconductor node in describing their typical feature sizes over successive generations of the ITRS roadmap in allowing the miniaturization of semiconductors in the industry.

Nanocomposite

A nanocomposite is a material that uses nano-sized particles into a matrix of standard materials. By adding nanoparticles into standard materials causes a drastic improvement in properties such as thermal conductivity, electrical conductivity, toughness, and mechanic strength. Nanoparticles are very effective in that a very small amount is added to the materials. In most cases, the amount added is about 5% of the weight of the materials. There are a number of material properties that drastically improve on addition on nanoparticles. They include optical clarity, surface appearance, chemical resistance, thermal stability, flame retardancy, reduced gas, water, and hydrocarbon permeability, electrical conductivity, and the mechanical properties such as dimensional stability, modulus, and strength.

Nanofabrication

Nanofabrication is defined as the process in which devices are designed and manufactured with their designs measures in nanometers. A nanometer is equal to a billionth of a meter or a millionth of a millimeter. Nanofabrication is mostly used by computer engineers as it creates an avenue to super-high-density microprocessors and memory chips. It was proposed that a single data bit could be stored in a single atom. With further advancements, a word of data or a byte could be represented by a single atom. Nanofabrication has also caught the eye of experts in the aerospace, military, and medical industry. There are several methods of nanofabrication. One technique involves the scaling down of integrated-circuits fabrication. Fabrication of integrated circuits has been done since the 1970s. The scaling down involved the removal of one atom at a time until the desired structure is achieved. Another method which is more sophisticated involves the assembly of a chip atom-by-atom, a process similar to bricklaying (Manjunatha et al., 2016). A more enhanced method is of the notion that a chip can assemble itself atom-by-atom by using programmable nanomachines. It is speculated that the biochips could be grown like a seed growing into a plant. The process is similar in that the components of the biochips would form by a process similar to cell division in living thing. The principles used in nanofabrication are similar to those used in microfabrication. The techniques under nanofabrication include molecular self-assembly, etching, bonding, film deposition, soft lithography, photolithography, focused ion beam lithography, colloidal monolayer, X-ray, rapid prototyping, and electron and electrically induced nanopatterning. These techniques are used in the fabrication of drug delivery and biosensing systems. There are two main types of nanofabrication which are the top-down approach and the bottom-up approach. The main goal of nanofabrication is the synthesis of ultra-fine and nano-sized materials. The top-down approach is perceived as an approach in which the building blocks are removed from substrates to form nanostructures. These nanostructures are synthesized by etching out the substrate. This results in the miniaturization of existing technologies. The technique is mostly used in the production of structures at the scale of a micrometer. It is also used in the fabrication of ICs as well as severe plastic deformation. The benefit of this approach is that it enables the inclusion of the required entity the exact areas. This is because the process is controlled externally. The bottom-up approach of fabrication is the approach where building blocks are added to substrates resulting in the formation of nanostructures. In this approach, the nanostructures are synthesized on the substrates through the assembling of atoms to form new substrates. They then stack on each other to produce nanostructures. This approach is mostly used in the formation of QDs. The nanoparticles in this case are formed through colloidal dispersion. The method is mostly used in chemical synthesis as it is involved in the building of more complex molecular devices atom by atom. The method is highly effective when used in the assembling and establishing of structures that are of short-range order and at the scale of nanometers. When compared to the top-down approach, the bottom-up approach is less expensive.

Nanofluidics

The study of the control, manipulation, and behavior of fluids confined within structures of nanometer as their characteristic dimension is nanofluidics. It was noted that when these fluids are confined in these structures, they exhibit physical behaviors that are not observed in larger structures like those structures whose measurements are in micrometers. This is because the characteristic physical scaling length of a fluid tend to coincide closely with the dimensions is the used nanostructures. The physical scaling lengths include the hydrodynamic radius and Debye length. As structures approach the size regime that corresponds to the molecular scaling lengths, the fluids exhibit a change in the new physical constraints causing a change in the fluid's behavior. For instance, the physical constraints create regions of the fluid to portray new properties that are not observed in bulk. The new properties could include a vastly increasing viscosity close to the pore wall whose effects may cause changes in thermodynamic properties. The effects could also change the chemical reactivity of the species while in the fluid-solid interface. A good demonstration of the change in properties is when an electrolyte solution is confined in nanopores containing surface charges. Electrified interfaces are said to induce organized charged distributions at the surface referred to as the electrical double layer. In most cases, the pores are measured in nanometer dimensions. For such pore the electrical double layer may entirely span the width of the nanopores (Marcato and Durán, 2008). The effects are the dramatic change in the composition of the fluid as well as the related properties of a fluid in motion within the structure. For instance, a drastic change in the surface-to-volume ratio of the pore causes a preponderance of counter-ions over co-ions. In most cases, the nearly complete exclusion of co-ions in that only one ionic species exists in the pore. This is beneficial in the manipulation of species with selective polarity along the pore length resulting in unusual fluidic manipulation schemes that cannot be achieved in structures measured in micrometer and other very large structures. Among the applications of nanofluidics is in the medical field where nanofluidics has a significant impact in-clinic diagnostics, medicine, and biotechnology. It has enabled the development of lab-on-a-chip (LOC) devices for certain techniques and PCR. Several attempts are being made to understand behaviors of flow fields around nanoparticles in terms of fluid forces being functions of Knudsen and Reynolds number computational fluid dynamics. The relationship between Reynolds number, drag, and lift has been noted to dramatically differ at the nanoscale level compared to the macroscale fluid dynamics.

Nanomanipulator

A nanomanipulator is device with microscopic viewing systems needed when working with object at a very extremely small scale. A nanorobot can be specialized to perform certain function and is called a nanomanipulator. This viewing system was designed at the University of North Carolina by the center for Computer Integrated Systems for Microscopy and Manipulation. The 3rd Tech Inc of Durham is the current manufacturers of nanomanipulators. They use the term nanomanipulator as a trademark. The company is located in North Carolina. A nanomanipulator system contains an optical scanning device, a physical manipulator, and a computer interface (Mei et al., 2011). The computer interface gives a large 3-D visual display a cause the effect of

Tele-Presence. This gives the user the impression that they are viewing an enlarged replica of the object. A scanned-probe microscope is a device that can magnify image by up to a million times. A manipulator gives a variable motion and force control. They include feedback and sensor devices that provide a feel of the object being examined. Interactions and sessions with a nanomanipulator can be shared among several users in different areas. The nanomanipulator has extensive applications in both the biological and physical sciences. These devices can be used to improve the characteristics of microchips, metal particles, disease pathogens, living cells, polymers, and CNTs (Figure 35).

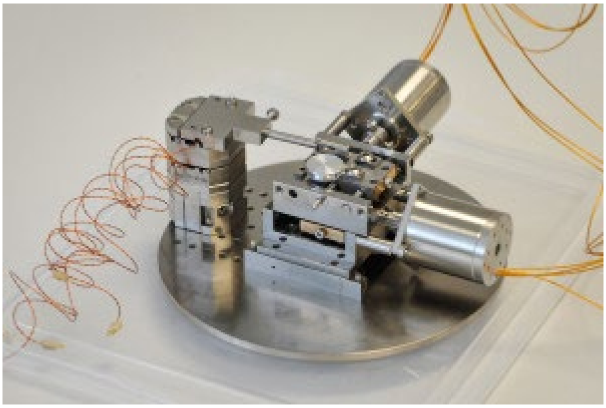


Figure 35. The nanomanipulator allows for movement of microstructures on a small-scale.

Source: http://nutimat.ee/en/nanomanipulator-en/.

Nanoporous

Nanoporous is a term used to describe a material. A nanoporous material is composed of a regular organic and inorganic bulk phase and has porous structures. These materials have pore dimensions that can suitably be quantified using units of nanometers. Usually, the diameter of pores in nanoporous material is usually 100 nanometers and, in some cases, they are smaller in size. Pores can either be closed or opened. Void fraction and pore connectivity can considerably change. In the case of open pores, they connect to the surface of the material while with closed pores they are pockets of void space in a bulk material. Catalysis studies, absorption, and separation techniques use open pores while closed pores are mostly used in structural applications and thermal insulators. Nanoporous materials can be grouped into membranes or bulk materials. Examples of bulk nanoporous materials include zeolites and activated carbon. Nanoporous membranes include cell membranes. A porous material or s porous medium is one that has pores. The frame or matrix is the skeleton part of the material. The pores are usually filled with fluid. Nanoporous materials can be classified as either naturally occurring or artificial nanoporous materials. The artificial nanoporous materials are those that can be synthesized. There are many methods of synthesizing nanoporous materials. One method involves the combination of polymers with various melting points. When the combination is heated, one polymer degrades. Nanoporous materials having a particular pore size has the characteristic of allowing certain substances to pass through while hindering others from entering it. Nanoporous materials can either be mesoporous or microporous. They are distinguished as different materials by their distinct applications afforded by sizes of pores within the material. Microporous materials are those that have pores whose sizes are smaller than nanoporous materials. For this reason, microporous materials are classified as a subset of nanoporous materials. These materials have pores whose diameters are less than 2 nm. Nanoporous materials are extensively used in the biological field. One of the areas include enzyme-catalyzed reactions where the materials are highly used in the metabolism and processing of large molecules. These materials allow the embedding of enzymes on a porous substrate thereby enhancing the lifetime of the reactions in long-term implants. Nanoporous materials are also used in DNA sequencing. Nanopores can be used in single-molecule analysis in that an inorganic nanoporous is coated on an insulating material. The DNA is thread through the nanopores enabling researchers to read out the ionic current flowing through the pores and can be correlated into one of four nucleotides.

Nanoscale

The nanoscale is also called the nanoscopic scale. It is used to refer to structures having a length scale that can be used to nanotechnology. In some cases, it is cited as 1–100 nanometers. As defined earlier, a nanometer is equal to a billionth of a meter. Roughly speaking, the nanoscopic scale in most solids is a lower bound to the mesoscopic scale. The nanoscopic scale in technical is the size in which fluctuations within average properties start to have a significant effect in the system’s behavior. This information is taken into consideration when conducting an analysis. The fluctuations within the averaged particles are as a result of the motion and the tendencies of individual particles. At times, the nanoscopic scale is marked as the point in which properties of materials change. Beyond this point, bulk, and volume effects causes the properties of the material. These properties include the kind of atoms present in the materials, the kind of bonds and the ratio of particles in the material (Mitter and Hussey, 2019). Below this point, there are changes in the material's properties though the types of atoms in the material and their relative orientations are very important. The changes cause the surface area effects to become more apparent. The effects are as a result of the geometry of the material. The small dimensions may cause drastic effects at the quantized state and generally the properties of the material. Stefan Hell, William Moerner and Eric Betzig were given the Nobel Prize in chemistry who were involved in the development of super-resolved microscopy that causes an optical microscopy in the nanodimension. The nanoscopic process of substrate presentations have been defined by super-resolution imaging. Examples of nanoscale include proteins. Proteins are said to be the most complex nanoscale molecular machines in cells and take the form of multi-protein complexes. Motor proteins are biological machines like myosin and are responsible for muscle contraction. Another motor protein is the kinesin whose function is the transportation of cargo from the nucleus of the cell along microtubules while dynein is involved in the transportation of cargo into the nucleus of the cells. It also generates the axonemal beating of flagella.

Nanoscience

Nanoscience is the study of materials and structures at an ultra-small scale as well as the interesting and unique properties demonstrated by these materials. Nanoscience is usually confused with nanotechnology. Nanoscience is a cross disciplinary in that scientists from various fields such as engineering, material science, computing, medicine, biology, physics, and chemistry are involved in the studies and using the generated information to better understand the world. Nanoscience forms the base for technology in various fields. The DOE office of science's office of basic energy sciences developed and established five nanoscale research centers to meet the demand. The established centers at the nanoscale conduct interdisciplinary collaborative research. They are able to give access to scientific expertise, computational tools, characterization, and leafing-edge synthesis. The establishment of these centers has created room for young scientists to be involved in the research process. They create structures and materials with high levels of atomic-scale precision in predicting, understanding, and characterizing their properties. These centers were located close to existing neutron and X-ray probes and also advanced computing facilities. This enables facilities to use most of the tools in tandem. A wide range of pioneering research in engineering and nanoscale science is supported by BES. Such research is very useful in the department of energy's goal to advance the national security, economic, and energy use in the U.S. This kind of discovery research created the foundation in which other scientists can look into other applications of nanotechnology. The advantage is that they get funding from the government and industry.

Nanosensors

Nanosensors are mechanical or chemical sensor devices that can be used in detecting the presence of nanoparticles and chemical species. They are also used in monitoring physical parameters like temperature in the nanoscale. They are considered to be platforms with certain dimensions in the nanometer scale. Nanosensors are very similar to other ordinary sensors, the only difference being the fact that they measure the quantities of very minute particles or miniscule quantities. Applications of nanosensors are very broad, and among the areas of applications is in medical diagnostics as well as water and food sensing. The working of nanosensors involves nanosensors being used to measure electrical changes in sensor materials (Mousavi and Rezaei, 2011). Nanosensors can either be mechanical sensors or chemical sensors. Nanosensors can be mechanical or chemical sensors as they are used in detecting various chemicals found in air thereby helping pollution monitoring. They can be used in medical diagnostics as blood-borne sensors. They can be used in monitoring physical parameters like flow, displacement, and temperature. Nanosensors can be used as accelerometers in devices such as airbag sensors. They are also used in studying neurotransmitters in the brain, allowing the generation of information on neurophysiology. Nanosensors can also be used to measure electrical changes. Nanosensors vary depending on the area of application. For instance, with MEMS systems using car airbags are dependent on monitoring changes in capacitance. Nanosensors have been modified to the point that they can take measurements at the level of a single molecule. Examples of nanosensors include the photoacoustic-based nanosensors, plasmon coupling-based nanosensors, plasmonic enhancing-/quenching-based nanosensors, magnetic resonance imaging-based nanosensors, peptide-based fluorescent nanosensors, multimodal nanosensors, carbon nanotube-based fluorescent nanosensors, DNA-based fluorescent nanosensors and quantum dot-based fluorescent nanosensors.

Nanotube

Carbon nanotubes (CNTs) are carbon tubes that have a diameter measured in nanometers. Single-wall carbon nanotubes (SWCNTs) with dimensions in the nanometer range are commonly referred to as CNTs. CNTs with a single wall are an allotrope of carbon that sits halfway between fullerene cages and flat graphene. SWCNTs can be imagined as cuttings from a two-dimensional hexagonal lattice of carbon atoms rolled up along one of the hexagonal lattice's Bravais lattice vectors to produce a hollow cylinder, albeit they are not made this way. Periodic boundary conditions are imposed along the length of the roll-up vector in this fabrication, resulting in a helical lattice of flawlessly connected carbon atoms on the cylinder surface (Figure 36).

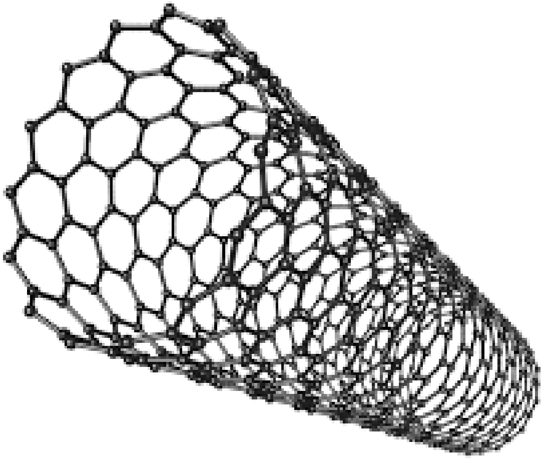


Figure 36. Carbon nanotubes are also known as multi-wall carbon nanotubes (MWCNTs), which are made up of nested single-wall carbon nanotubes that are weakly bonded together in a tree ring-like structure by van der Waals interactions.

Source: https://phys.org/news/2016-09-team-accurately-permeability-carbon-nanotubes.html.

These tubes resemble Oberlin, Endo, and Koyama's long straight and parallel carbon layers cylindrically stacked around a hollow tube, if not identical. Double- and triple-wall carbon nanotubes are also referred to as multi-wall carbon nanotubes. Tubes with an unknown carbon-wall structure and diameters smaller than 100 nanometers are also referred to as CNTs.

Radushkevich and Lukyanovich found such tubes in 1952. While other types of nanotubes exist, the majority of study has concentrated on CNTs. As a result, the qualifier “carbon” is frequently taken out of acronyms, and the names are abbreviated NT, SWNT, and MWNT. The length of a carbon nanotube made using ordinary manufacturing processes is rarely recorded, however it is usually significantly longer than its diameter. End effects are thus ignored for many purposes, and the length of CNTs is considered to be endless (Morrow et al., 2007).

While some CNTs have a high electrical conductivity, others are semiconductors. Because of their nanostructure and the strength of the connections between carbon atoms, they exhibit remarkable tensile strength and thermal conductivity. Furthermore, they can be chemically altered. Many fields of technology, including electronics, optics, composite materials (replacing or complementing carbon fibers), nanotechnology, and other materials science applications, are predicted to benefit from these features.

Rolling up a hexagonal lattice in different orientations to generate distinct infinitely long SWCNTs reveals that they all have helical, translational, and rotational symmetry along the tube axis, with many having nontrivial rotational symmetry about this axis. Furthermore, the majority of them are chiral, which means that the tube and its mirror counterpart cannot be overlaid. This structure also permits a pair of integers to be used to designate SWCNTs. All achiral SWCNTs are either tiny or intermediate bandgap semiconductors, with the exception of a small group of metallic nanotubes. These electrical characteristics, on the other hand, are the same for the tube and its mirror counterpart, regardless of whether the hexagonal lattice is rolled from back to front or front to back.

The expense of CNTs has been a major impediment to their use. As of March 2010, retail pricing for single-walled nanotubes had dropped from approximately $1,500 per gram in 2,000 to around $50 per gram of as-produced 40–60% by weight SWNTs. The retail price of 75% by weight SWNTs as produced in 2016 was $2 per gram. The current use and application of nanotubes has mostly been limited to bulk nanotubes, which are a mass of disorganized nanotube fragments. Although bulk nanotube materials will never have the same tensile strength as individual tubes, such composites may have enough strength for many purposes. CNTs in bulk have already been employed as composite fibers in polymers to improve the bulk product’s mechanical, thermal, and electrical qualities.

Nano Characterization

In the context of the REACH regulation of nanomaterials, nano reference measurement methods are becoming increasingly significant in the EU. BAM offers a variety of measurement methods on-site, all of which are managed by highly qualified staff who use and develop the procedures with extreme precision and accuracy. The fields of shape and morphology, size distribution, particular surface, chemical composition, and surface chemistry are currently the key focus in the precise characterization of nanomaterials. The internal instrument division of BAM will be incorporated into this, allowing for the employment of a rising number of instruments and procedures together (Mnyusiwalla et al., 2003).

Characterization of nanoparticles is a branch of nanometrology concerned with the identification and measurement of nanoparticles' physical and chemical properties. Nanoparticles have at least one exterior dimension of fewer than 100 nanometers and are frequently developed for their unique features. Nanoparticles differ from typical chemicals in that their chemical composition and concentration are insufficient for a complete description because they vary in size, shape, surface characteristics, crystallinity, and dispersion state, among other physical attributes.

Nanoparticles are studied for a variety of reasons, including nanotoxicology research and workplace exposure assessments to assess health and safety risks, as well as manufacturing process control. Microscopy and spectroscopic approaches, as well as particle counts, are among the instruments used to measure these features. Many organizations offer nanotechnology metrology standards and reference materials, despite the fact that nanotechnology is still a relatively new science. Advanced nanomaterials characterization is a crucial field that leads to the discovery of their structure-properties relationship and defines their possible uses in modern nano and biotechnology. Nanomaterials' size, form, crystal structure, chemical properties, optical, magnetic, and mechanical characteristics have all been studied using various approaches.

Nanocomposites

Nanocomposite is a multiphase solid material with one, two, or three dimensions of less than 100 nanometers (nm) and nanoscale repeat distances between the distinct phases that make up the material. Nanocomposite is based on the concept of using nanoscale building pieces to design and manufacture new materials with exceptional flexibility and improved physical qualities. This term can include porous media, colloids, gels, and copolymers in the broadest sense, although it is most commonly used to refer to the solid combination of a bulk matrix and nano-dimensional phase(s) with properties that differ due to differences in structure and chemistry. The nanocomposite's mechanical, electrical, thermal, optical, electrochemical, and catalytic properties will be significantly different from those of the component materials. These effects have been given size constraints (Figure 37).

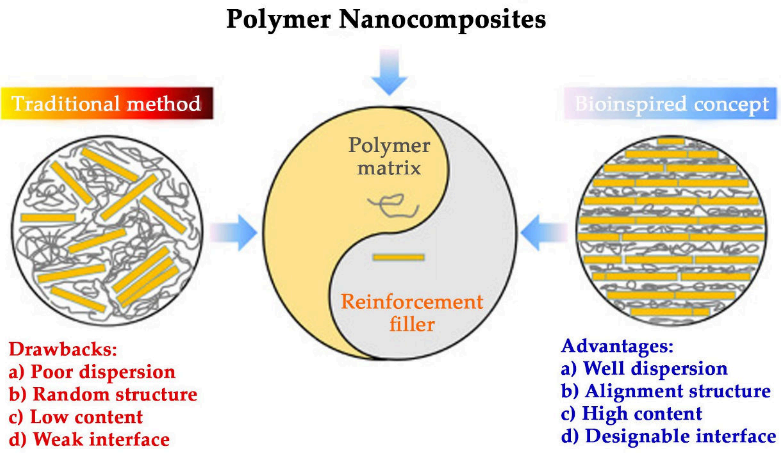


Figure 37. Nanocomposites can be found in nature, such as the abalone shell and bone structure.

Source: https://www.sciencedirect.com/science/article/pii/S026635381730965X.

The application of nanoparticle-rich materials precedes our understanding of their physical and chemical properties. Jose-Yacaman et al. looked into the origins of Maya blue paint's color depth, acid resistance, and bio-corrosion resistance, and found that it was due to a nanoparticle mechanism. Nanoscale organo-clays have been utilized to control the flow of polymer solutions and the formation of gels since the mid-1950s. Polymer/clay composites were the subject of textbooks by the 1970s, though the word "nanocomposites" was not widely used at the time.

Nanocomposites differ mechanically from ordinary composite materials due to the reinforcing phase's very high surface to volume ratio and/or its exceptionally high aspect ratio. Particles (e.g., minerals), sheets (e.g., exfoliated clay stacks), or fibers can be used as reinforcing material (e.g., CNTs or electrospun fibers). In comparison to conventional composite materials, the area of the interface between the matrix and reinforcing phase(s) is generally an order of magnitude larger (Xia, 2008).

In the area of the reinforcement, the matrix material properties are dramatically influenced. Properties related to local chemistry, degree of thermoset cure, polymer chain mobility, polymer chain conformation, degree of polymer chain ordering, or crystallinity can all vary significantly and continuously from the interface with the reinforcement into the bulk of the matrix, according to Ajayan et al. With polymer nanocomposites, properties related to local chemistry, degree of thermoset cure, polymer chain mobility, polymer chain conformation, degree of polymer chain ordering, or crystallinity can all vary.

Because of the high surface area of the reinforcement, even a small amount of nanoscale reinforcement can have a visible effect on the composite's macroscale properties. CNTs, for example, improve electrical and thermal conductivity. Other types of nanoparticulates may have improved optical, dielectric, or heat resistance capabilities, as well as mechanical properties including stiffness, strength, and wear and damage resistance. During processing, the nano reinforcement is spread throughout the matrix.

Due to the low filler percolation threshold, the proportion by weight (called mass fraction) of nanoparticulates introduced can stay very low (on the order of 0.5% to 5%), especially for the most often employed non-spherical, high aspect ratio fillers (e.g., nanometer-thin platelets, such as clays, or nanometer-diameter cylinders, such as CNTs). The effective thermal conductivity of nanocomposites is influenced by the orientation and arrangement of asymmetric nanoparticles, thermal property mismatch at the interface, interface density per unit volume of nanocomposite, and nanoparticle polydispersity.

Nanocrystalline (NC) Materials

A nanocrystalline (NC) material is a polycrystalline material having nanometer-sized crystallites. These materials bridge the gap between amorphous materials with no long-range organization and coarse-grained materials that are commonly used. NC material is characterized as having a crystallite (grain) size of less than 100 nanometers. Grain diameters of 100–500 nm is sometimes referred to as "ultrafine" grains.

X-ray diffraction can be used to measure the grain size of an NC sample. The diffraction peaks will be widened in materials with very small grain sizes. The Scherrer equation (applicable up to 50 nm), a Williamson-Hall plot, or more complex approaches such as the Warren-Averbach method or computer modeling of the diffraction pattern can all be used to connect this broadening to a crystallite size. Transmission electron microscopy can be used to measure the crystallite size directly (Weiss et al., 2020).

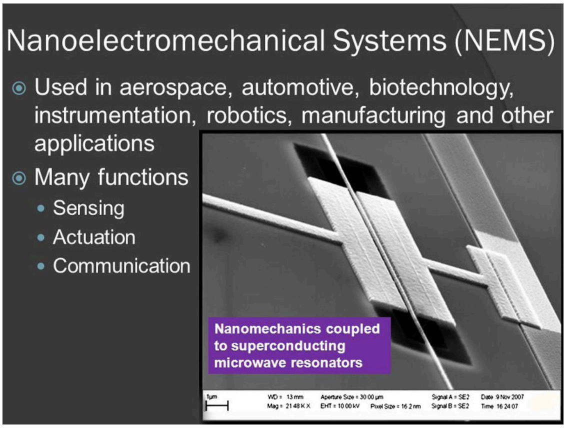
In comparison to coarse-grained materials, NC materials have superior mechanical characteristics. Because the volume percentage of grain borders in NC materials can be as high as 30% (Kung and Kung, 2004), this amorphous grain boundary phase has a major impact on the mechanical properties of NC materials. The elastic modulus of NC metals, for example, has been demonstrated to fall by 30% and by more than 50% in NC ionic materials.

While the synthesis of NC feedstocks in the form of foils, powders, and wires is relatively simple, the tendency of NC feedstocks to coarsen when exposed to elevated temperatures necessitates the use of low-temperature and rapid densification techniques to consolidate them into bulk components. Although the synthesis of bulk NC components on a commercial scale remains unfeasible, a range of approaches, such as spark plasma sintering or ultrasonic additive manufacturing, show promise in this regard.

Nanoelectromechanical Systems (NEMS)

Nanoelectromechanical systems (NEMS) are a type of nanoscale technology that combines electrical and mechanical functions. From microelectromechanical systems (MEMS), or MEMS devices, NEMS are the next logical miniaturization step. Physical, biological, and chemical sensors can be made using NEMS, which combine transistor-like nanoelectronics with mechanical actuators, pumps, or motors. The name comes from the fact that typical device dimensions are in the nanometer range, resulting in low mass, high mechanical resonance frequencies, potentially large quantum mechanical effects such as zero-point motion, and a high surface-to-volume ratio, which is useful for surface-based sensing mechanisms (Arora et al., 2014).

There are many possible uses of machines at lower and smaller scales, as stated by Richard Feynman in his famous 1959 address, “There’s Plenty of Room at the Bottom.” By developing and manipulating devices at smaller scales, all technology benefits. In electromechanical systems, the projected benefits include increased efficiency and reduced size, reduced power consumption, and cheaper production costs (Figure 38).



Nanoelectromechanical Systems (NEMS)

- Used in aerospace, automotive, biotechnology, instrumentation, robotics, manufacturing and other applications
- Many functions
  - Sensing
  - Actuation
  - Communication

Nanomechanics coupled to superconducting microwave resonators

1µm
WD = 13 mm
Mag = 21.48 K X
Aperture Size = 30.00 µm
EHT = 10.00 kV
Pixel Size = 16.2 nm
Signal A = SE2
Signal B = SE2
Date :9 Nov 2007
Time :16:24:07

Figure 38. Low yields and excessive device quality variability are two major roadblocks to the commercialization of many NEMS devices.

Source: https://idstch.com/technology/materials/nanoelectromechanical-systems-nems-sensing-displays-portable-power-generation-energy-harvesting-drug-delivery-imaging/.

At Bell Labs, Mohamed M. Atalla and Dawon Kahng built the first MOSFET with a gate oxide thickness of 100 nm in 1960. In 1962, Atalla, and Kahng employed gold (Au) thin films with a thickness of 10 nm to create a nanolayer-base metal-semiconductor junction (M-S junction) transistor. Bijan Davari headed an IBM team that demonstrated the first MOSFET with a 10 nm oxide layer in 1987. Starting with the FinFET, multi-gate MOSFETs enabled scalability below 20 nm channel length. Digh Hisamoto's study at Hitachi Central Research Laboratory in 1989 led to the development of the FinFET.

Before NEMS devices may be utilized, suitable carbon-based product integrations must be developed. Diamond has taken a recent breakthrough in this regard, achieving a processing level comparable to that of silicon. The emphasis is now turning away from experimental work and toward practical applications and device structures that will implement and profit from innovative gadgets. Understanding all of the qualities of these carbon-based tools and exploiting those properties to create efficient and durable NEMS with low failure rates is the next obstacle to overcome. Because of their superior mechanical and electrical qualities, carbon-based materials have been chosen as the primary materials for NEMS. By 2022, the global market for NEMS is expected to reach $108.88 million.

Nanofiber

Nanofibers are fibers with a diameter of less than a nanometer. Nanofibers can be made from a variety of polymers and so have a variety of physical properties and applications. Collagen, cellulose, silk fibroin, keratin, gelatin, and polysaccharides like chitosan and alginate are examples of natural polymers. Poly (lactic acid) (PLA), polycaprolactone (PCL), polyurethane (PU), poly (lactic-co-glycolic acid) (PLGA), poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), and poly(ethylene-co-vinyl acetate) are some examples of synthetic polymers (PEVA). Covalent bonds are used to join polymer chains. Nanofiber sizes are determined by the polymer used and the manufacturing procedure. When compared to their microfiber counterparts, all-polymer nanofibers have a significant surface-area-to-volume ratio, high porosity, appreciable mechanical strength, and functionalization flexibility (West and Halas, 2000).

Drawing, electrospinning, self-assembly, template fabrication, and thermal-induced phase separation are only a few of the methods for creating nanofibers. Because of its simple setup, capacity to mass-produce continuous nanofibers from diverse polymers, and ability to make ultrathin fibers with adjustable diameters, compositions, and orientations, electrospinning is the most widely used technology for generating nanofibers. This flexibility provides for control over the shape and arrangement of the fibers, allowing for the fabrication of various structures (i.e., hollow, flat, and ribbon shaped) depending on the desired use. Scientists and engineers at the University of Minnesota have created nanofibers as thin as 36 nanometers using a new melt processing approach that is suitable for industrial mass manufacturing.

To support and guide cell proliferation and tissue regeneration in tissue engineering, a highly porous artificial extracellular matrix (ECM) is required. Biodegradable polymers, both natural and synthetic, have been employed to make these scaffolds. Simon demonstrated that electrospinning may be utilized to manufacture nano- and submicron-scale polystyrene and polycarbonate fiber mats specifically designed for use as in vitro cell substrates in a 1988 NIH SBIR award report. Human foreskin fibroblasts (HFF) transformed Human Carcinoma (HEp-2), and mink lung epithelium (MLE) adhered to and proliferated upon the fibers in this early usage of electrospun fibrous lattices for cell culture and tissue engineering.

Although pathologic evaluation is the current gold standard for molecular characterization in tumor testing for biomarkers, single-sample analyzes fail to account for tumors' heterogeneous genetic composition. Given the invasive nature, psychological stress, and financial burden that patients face as a result of frequent tumor biopsies, biomarkers that may be assessed using less invasive procedures such as blood draws represent an opportunity for advancement in precision medicine. In recent years, polymer optical fibers have piqued people's interest. Polymer optical fibers have a lot of potential for short-distance networking, optical sensing, and power transmission because of its low cost, ease of handling, long-wavelength transparency, excellent flexibility, and biocompatibility.

Nanofluidics

Nanofluidics is the study of the behavior, manipulation, and control of fluids restricted to structures with characteristic dimensions of nanometers (usually 1–100 nm) (1 nm = 109 m). Because the characteristic physical scaling lengths of the fluid (e.g., Debye length, hydrodynamic radius) very closely coincide with the dimensions of the nanostructure itself, fluids confined in these structures exhibit physical behaviors not seen in larger structures, such as those of micrometer dimensions and above (Figure 39).

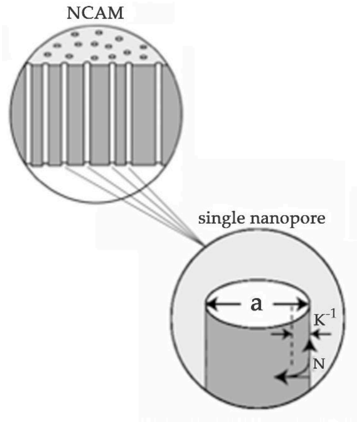


Figure 39. Electrolyte solutions confined in nanopores that contain surface charges, i.e., at electrified surfaces, are a particularly relevant and practical example, as seen in the nanocapillary array membrane (NCAM).

Source: https://en.wikipedia.org/wiki/Nanofluidics.

When structures approach the size regime corresponding to molecule scaling lengths, the fluid's behavior is subjected to new physical limitations. For example, these physical restrictions may cause changes in thermodynamic properties and affect the chemical reactivity of species at the fluid-solid interface, causing parts of the fluid to exhibit novel qualities not seen in bulk, such as substantially increased viscosity near the pore wall (Thompson, 2011).

The electrical double layer is an organized charge distribution at the surface that is induced by all electrified surfaces. The electrical double layer may entirely cross the width of the nanopore in pores of nanoscale dimensions, resulting in substantial changes in the fluid composition and related aspects of fluid motion in the structure. For example, the pore's dramatically increased surface-to-volume ratio results in a preponderance of counter-ions (ions charged in the opposite direction of the static wall charges) over co-ions (ions with the same sign as the wall charges), in many cases to the near-complete exclusion of co-ions, resulting in the pore having only one ionic species.

Nanolithography (NL)

Nanolithography (NL) is a burgeoning field of nanotechnology techniques that deals with the engineering (patterning, such as etching, depositing, writing, printing, and so on) of nanometer-scale structures on a variety of materials. The current word refers to buildings that are designed in the region of 109 to 106 meters, or nanoscale scale. The field is essentially a lithography derivative that exclusively deals with very small structures. Photolithography, scanning lithography, soft lithography, and other miscellaneous techniques are the four groups of NL technologies.

The NL arose from the necessity to stay up with Moore's Law by increasing the number of sub-micrometer features (e.g., transistors, capacitors, etc.), in an integrated circuit. While lithographic techniques have existed since the late 1800s, none were used to create nanoscale structures until the mid-1950s. Demand for technology capable of generating micro- and nanoscale structures soared as the semiconductor industry evolved. In 1958, photolithography was used for the first time on these structures, ushering in the age of NL.

Photolithography has since become the most commercially effective technology, capable of generating patterns as small as 100 nanometers. The field is related with a number of approaches, each of which is designed to fulfill a specific purpose in the medical and semiconductor sectors. Breakthroughs in this field are critical for the growth of nanotechnology, and they are becoming more vital as the need for smaller and smaller computer chips grows. Physical constraints of the field, energy harvesting, and photonics are some of the other fields of inquiry.

Nanomanipulation

Nanomanipulation is the process of moving or changing objects on an atomic or molecular scale. Nanomanipulation is divided into two categories: nanofabrication and self-assembly, and it is used to create incredibly precise structures. The use of tools to shape or manufacture a variety of products, materials, or structures at atomic level precision is known as nanofabrication. Nanofabrication is typically accomplished by removing microscopic particles (even individual atoms and molecules) from a material until the desired structure is attained, or by building the material up atom by atom or molecule by molecule. The first process resembles carving from a block of wood or stone, while the second resembles bricklaying. A piece of equipment known as a nanomanipulator is required to accomplish this.

Modified atomic force microscopes (AFM) and scanning tunneling microscopes (STM), which were originally designed for various uses, are now widely employed as nanomanipulators. Single atoms can be lifted, relocated, replaced, and otherwise manipulated by changing the charge (polarity) as well as the magnitude and length of the voltage pulse between the microscope tip and the sample surface (Sozer and Kokini, 2009).

Self-assembly is a branch of nanotechnology concerned with the self-assembly of nanoscale materials, goods, devices, and systems without the assistance of external tools. They, in effect, construct themselves. Self-assembly is a bottom-up method in which components arrange themselves into structured units or patterns from a starting point rather than being sculpted by material removal as in NL (a top-down process).

Nanomaterials

Nanomaterials are materials with a single unit sized (in at least one dimension) between 1 and 100 nanometers (the conventional definition of nanoscale). Nanomaterial's research uses improvements in materials metrology and synthesis gained in support of microfabrication research to take a materials science-based approach to nanotechnology. Nanostructured materials often exhibit unique optical, electrical, thermo-physical, and mechanical capabilities. Nanomaterials are gradually becoming more commercialized and becoming commodities.

The European Commission adopted the exact description of a nanomaterial on October 18, 2011: "A natural, incidental, or manufactured material granular materials in an unbound state, as an aggregate, or as an agglomerate, with one or more external dimensions in the size range 1 nm–100 nm for 50% or more of the particles in the number size distribution. The 50% number size distribution criterion may be substituted by a threshold between 1 and 50% in specific instances where concerns about the environment, health, safety, or competitiveness demand it "From 10% to 50%" (Figure 40).

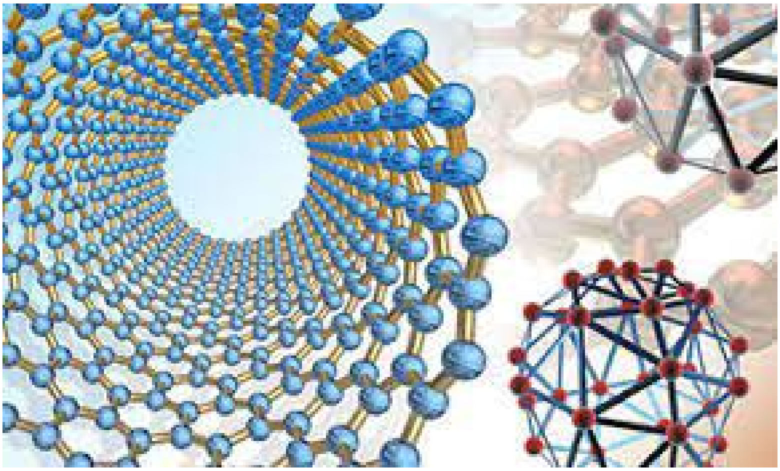


Figure 40. Furthermore, any changes in packing density in the compact as it is prepared for the kiln are frequently magnified throughout the sintering process, resulting in inhomogeneous densification.

Source: https://www.niehs.nih.gov/health/topics/agents/sya-nano/index.cfm.

Many nano-objects are classified according to how many of their dimensions are nanoscale. A nanoparticle is a nano-object with all three exterior dimensions in the nanoscale and no notable difference between the longest and shortest axes. In the nanoscale, a nanofiber has two exterior dimensions: nanotubes are hollow nanofibers, while nanorods are solid nanofibers. In the nanoscale, a nanoplate/nanosheet has one exterior dimension, and a nanoribbon has two bigger dimensions that are drastically different. The other dimensions of nanofibers and nanoplates may or may not be in the nanoscale, but they must be much larger.

The phases of matter that nanostructured materials include are frequently used to classify them. A nanocomposite is a solid that has at least one physically or chemically different region, or group of regions, with at least one nanoscale dimension. A nanofoam is made out of a liquid or solid matrix filled with a gaseous phase, one of which has nanoscale dimensions. A solid material with nanopores, voids in the form of open or closed pores with sub-micron length scales, is called a nanoporous material. The nanoscale contains a substantial fraction of crystal grains in a NC substance (Smith et al., 2013).

High purity ceramics, polymers, glass-ceramics, and material composites are used in the chemical processing and synthesis of high-performance technical components for the private, industrial, and military sectors. The variable sizes and shapes of nanoparticles in a typical powder often lead to non-uniform packing morphologies in condensed bodies generated from fine powders, resulting in packing density differences in the powder compact.

Microstructural inhomogeneities can be caused by uncontrolled aggregation of powders due to attractive van der Waals forces. Differential stresses that emerge as a result of non-uniform drying shrinkage are directly proportional to the rate at which the solvent may be removed, making porosity distribution extremely important. Such stresses have been linked to a plastic-to-brittle transition in consolidated materials, and if not released, they can result in crack propagation in the unfired body.

Pores and other structural defects linked to density fluctuations have been proven to impede sintering by increasing and hence restricting end-point densities. Differential stresses caused by inhomogeneous densification have also been demonstrated to propagate inside fractures, resulting in the formation of strength-controlling defects.

Nanometer

A nanometer (NM) is a measuring unit that is 1 billionth of a meter in length. It is commonly used in nanotechnology as a scale for manufacturing tiny, sophisticated, and atomic size computing and electronic components. The nanometer, or nanometer (American spelling), is a metric measure of length equal to 1 billionth of a meter. It is commonly used in Nanotechnology. The nanometer's official symbol in the International System of Units (SI) is nm. The prefix nano- (dwarf) is combined with the parent unit name meter in the name (unit of measurement). It is 1/1009 m in scientific notation, 1 E9 m in engineering notation, and 1/1,000,000,000 m in simple notation. Around

10 angstroms equal one nanometer. On an atomic scale, the nanometer is frequently used to express dimensions.

Because it is 1/1000 of a micron (micrometer), the nanometer was previously known as the millimicrometer or millimicron and was often indicated by the symbol m or (less commonly). The prefix "nano-" meaning "a billionth" was approved by the US National Bureau of Standards in 1960. Nanotechnology is frequently related with the nanometer. It has also been used to characterize generations of production technology in the semiconductor sector from the late 1980s (Abolmaali et al., 2013).

Nanoparticles

A nanoparticle, also known as an ultrafine particle, is a small particle of matter with a dimension of 1 to 100 nanometers (nm). The name is also applied to bigger particles with diameters of up to 500 nm, as well as fibers and tubes with diameters of less than 100 nm in only two directions. Metal particles less than 1 nm are commonly referred to as atom clusters instead. Nanoparticles are separated from microparticles (1–1,000 m), "fine particles," and "coarse particles" (ranging from 2,500 to 10,000 nm) by their smaller size, which affects physical and chemical properties such as colloidal properties, optical properties, and electric properties.

Nanoparticles cannot be detected with standard optical microscopes because their wavelengths are substantially shorter than visible light wavelengths (400–700 nm), necessitating the use of electron microscopes or laser microscopes. Dispersions of nanoparticles in transparent liquids can be transparent for the same reason, although suspensions of bigger particles reflect some or all visible light striking on them. Nanoparticles easily flow through ordinary filters, such as standard ceramic candles, necessitating the use of sophisticated nanofiltration procedures to separate them from liquids.

Nanoparticles have features that differ significantly from larger particles of the same substance. Because an atom's diameter is typically between 0.15 and 0.6 nm, a major portion of the nanoparticle's substance is found within a few atomic diameters of its surface. As a result, the top layer's properties may take precedence over those of the bulk material. Because the interactions between the two materials at their interface become considerable, this effect is especially powerful for nanoparticles distributed in a liquid of dissimilar composition (Figure 41).

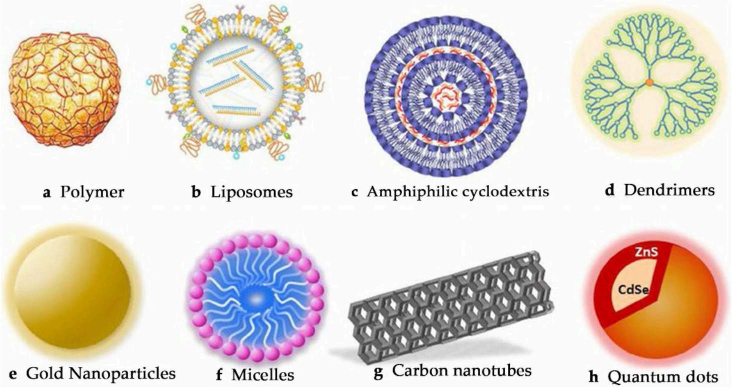


Figure 41. Nanoparticles are found all throughout nature and are studied in a variety of fields including chemistry, physics, geology, and biology.

Source: https://www.researchgate.net/figure/Different-types-of-nanoparticles-commonly-used-for-biomedical-applications-and-which_fig2_269182214.

They frequently display behaviors that are not observed at either size because they are at the interface between bulk materials and atomic or molecular structures. They are a major source of pollution in the atmosphere and are used in a variety of industrialized items such as paints, plastics, metals, ceramics, and magnetic products. Nanotechnology includes the creation of nanoparticles with specialized properties.

Nanoporous Materials

A normal organic or inorganic bulk phase with a porous structure constitutes nanoporous materials. Nanoporous materials have pore sizes that are best measured in nanometers. Pores in nanoporous materials typically have a diameter of 100 nanometers or less. As with other porous materials, pores can be open or closed, and pore connectivity and void percentage vary greatly. Closed pores are pockets of vacuum space within a bulk material, whereas open pores connect to the substance's surface. Open pores can be used in molecular separation, adsorption, and catalysis experiments (Baruah and Dutta, 2009). The majority of nanoporous materials fall into one of two categories: bulk materials or membranes. Bulk nanoporous materials, such as activated carbon and zeolites, can be thought of as nanoporous membranes, while cell membranes can be thought of as nanoporous membranes. A porous media, often known as a porous material, is one that contains pores (voids). The "matrix" or "frame" refers to the skeletal portion of the material. A fluid is usually injected into the pores (liquid or gas). Natural nanoporous materials abound, but manmade nanoporous materials can also be created. Combining polymers with differing melting points, for example, allows one polymer to deteriorate when heated.

Nanoshell

0A nanoshell, or rather a nanoshell plasmon, is a spherical nanoparticle with a dielectric core and a thin metallic shell around it (usually gold). These nanoshells use a quasiparticle termed a plasmon, which is a collective excitation of quantum plasma oscillation in which all of the ions' electrons vibrate at the same time. The tunability of the oscillation is related with a mixing of the inner and outer shells where they hybridize to give a lower or greater energy. This is referred to as plasmon hybridization. This lower energy forms a strong bond with incident light, whereas the higher energy forms an anti-bond and only weakly combines with it. Because the hybridization interaction is stronger for thinner shell layers, the wavelength of light it links with is determined by the thickness of the shell and overall particle radius.

Nanoshells can be created in a wide range of light wavelengths, including visible and near-infrared. The coupling strength is affected by the interaction of light with nanoparticles, which modifies the arrangement of charges. The charges are further away from the substrate surface when incident light is polarized parallel to the substrate, resulting in a stronger contact between the shell and core. Otherwise, a p-polarization is created, resulting in a plasmon energy shift that is more strongly shifted, resulting in a weaker contact, and coupling.

Microfluidic Composite Foams are a state-of-the-art technology for producing gold nanoshells. This technology has the potential to replace the traditional lithographic method of plasmonic nanoshell fabrication. Suhanya Duraiswamy and Saif A. Khan of Singapore's Department of Chemical and Biomolecular Engineering conducted an experiment that resulted in the production procedure mentioned below. Despite being an experiment, this technology symbolizes the future of nanoshell fabrication.

Nanostructures

A nanostructure is a structure that lies halfway between microscopic and molecular structures in terms of size. At the nanoscale, nanostructural detail is microstructure. When characterizing nanostructures, it is important to distinguish between the number of nanoscale dimensions in the volume of an object. On the nanoscale, nanotextured surfaces have only one dimension, i.e., the thickness of an object's surface is between 0.1 and 100 nm. On the nanoscale, nanotubes have two dimensions: the width of the tube is between 0.1 and 100 nm, and the length of the tube can be much longer (Bohr, 2002).

Finally, spherical nanoparticles have three dimensions on the nanoscale, with each spatial dimension ranging between 0.1 and 100 nanometers. Although UFP can extend into the micrometer range, the terms nanoparticles, and ultrafine particles (UFP) are frequently used interchangeably. When it comes to magnetic technology, the term nanostructure is frequently employed. Ultrastructure is a term used in biology to describe nanoscale structure.

NMR (Nuclear Magnetic Resonance) Spectroscopy

The spectroscopic technique of nuclear magnetic resonance spectroscopy (MRS), often known as NMR spectroscopy or MRS, is used to study local magnetic fields around atomic nuclei. The NMR signal is formed by excitation of the nuclei sample with radio waves into nuclear magnetic resonance, which is detected using sensitive radio receivers, and the sample is put in a magnetic field. The resonance frequency of an atom in a molecule is changed by the intramolecular magnetic field around it, allowing access to specifics of the molecule's electronic structure and individual functional groups.

NMR spectroscopy is the definitive method for identifying monomolecular organic compounds in modern organic chemistry practice since the fields are unique or highly distinctive to specific molecules. Biochemists use NMR to identify proteins and other complex compounds in the same way. NMR spectroscopy offers precise information about the structure, dynamics, reaction state, and chemical environment of molecules in addition to identifying them. Proton and carbon-13 NMR spectroscopy are the most popular types of NMR spectroscopy, but it can be used on any sample with spin-containing nuclei.

NMR spectrometers are relatively expensive; institutions typically have them, but commercial enterprises are less likely to have them. An NMR spectrometer cost between 500,000 and 5 million dollars between 2000 and 2015. Because resolution is directly proportional to magnetic field strength, modern NMR spectrometers contain a powerful, massive, and expensive liquid helium-cooled superconducting magnet. There are also less expensive machines with permanent magnets and lesser resolution that provide enough performance for specific applications such as reaction monitoring and sample verification. There are also nuclear magnetic resonance spectrometers that may be used on a tabletop.

Noncovalent Interactions

A non-covalent connection differs from a covalent link in that it involves more distributed variations of electromagnetic interactions between molecules or inside a molecule rather than the exchange of electrons. Non-covalent interactions release chemical energy in the range of 1–5 kcal/mol (1,000–5,000 calories per 6.02 1023 molecules). Electrostatic contacts, -effects, van der Waals forces, and hydrophobic interactions are all examples of non-covalent interactions.

Large molecules, such as proteins and nucleic acids, rely on non-covalent interactions to preserve their three-dimensional structure. Furthermore, they are involved in a variety of biological processes in which big molecules bond to one another in a precise yet transitory manner (see the properties section of the DNA page). These interactions also have a significant impact on drug design, crystallinity, and material design, particularly for self-assembly, and the synthesis of many organic compounds in general. Non-covalent interactions between separate molecules, rather than between different atoms of the same molecule, are known as intermolecular forces (Bhattacharyya et al., 2009).

Most pharmacological medications are tiny compounds that elicit a physiological reaction by “binding” to enzymes or receptors, causing the enzyme’s ability to operate to raise or decrease. Although certain medications do covalently affect an active site, the binding of a small molecule to a protein is determined by a mix of steric, or spatial, considerations as well as numerous non-covalent interactions (see irreversible inhibitors). A medication (key) must be roughly the right size to suit the enzyme’s binding site, according to the “lock and key” model of enzyme binding (lock).

O

Oxidation Sent from Smartphone

The smartphone can sometimes feel like an arcane bit of sorcery, despite the fact that it rarely leaves our hands. And nowhere is this more apparent than with the finicky battery, which can lose 20% of its charge faster than you can turn off Bluetooth and eventually die after a few of years of charging. To compensate for these shortcomings, we have created a slew of battery myths. We are always seeking for methods to eke out a bit more performance from our overworked batteries, even if the method does not make a lot of sense, whether it is avoiding putting your phone on charge overnight or shutting off to give the battery a little break.

Although there is more charge in your smartphone battery than the percentage displayed shows, using that juice would drastically reduce the battery's total lifespan. A delicate trade-off performed by manufacturers is at the heart of this issue. The number of times a battery can be charged and drained without being harmed decreases as the available charge within the battery increases. Manufacturers limit the amount of juice that batteries may discharge to ensure that they last for hundreds or thousands of charge cycles (Bowman and Hodge, 2007).

To understand why, you must first grasp how batteries function. Most lithium-ion batteries, such as those found in smartphones, laptops, and electric vehicles, include two layers: one of lithium cobalt oxide and the other of graphite. When lithium ions migrate from the graphite layer to the lithium cobalt oxide layer, energy is released. When you charge a battery, the lithium ions are simply shifted back the other way, out of the lithium cobalt oxide layer and back to the graphite. So, while a battery can be charged beyond 100%, the only way to do so is to remove more of those critical lithium ions. “It’d be like ripping all the supports out of a building’s floor,” Griffith says. You might be able to pull the lithium ions out, but you will have a hard time putting them back if you have messed up the internal structure.

P

Photolithography

Photolithography, commonly known as optical or UV lithography, is a microfabrication technique for patterning parts on a thin film or the majority of a substrate (also called a wafer). A geometric design is transferred from a photomask (also known as an optical mask) to a photosensitive (light-sensitive) chemical photoresist on the substrate using light. Following that, a succession of chemical treatments either etches the exposure pattern into the material or allows for the deposition of a new material in the required pattern onto the material beneath the photoresist. A CMOS wafer may go through the photolithographic cycle up to 50 times in complicated integrated circuits (ICs) (Lakhal and Wood, 2011).

The pattern in the photoresist etching is generated by exposing it to light, either directly (without using a mask) or with a projected image using a photomask. Photolithography shares some essential principles with photography in that the pattern in the photoresist etching is made by exposing it to light, either directly (without using a mask) or with a projected image using a photomask. This procedure is analogous to a high-precision variant of the printed circuit board manufacturing process. The following phases of the process are more akin to etching than lithographic printing. This approach can produce designs as small as a few tens of nanometers in size.

For many years, photolithography has defied predictions of its extinction. Many in the semiconductor industry, for example, believed that features smaller than 1 micron could not be printed optically by the early 1980s. Modern excimer laser lithography techniques can now print features with diameters that are a fraction of the wavelength of light employed – an incredible optical accomplishment. Immersion lithography, dual-tone resist, and multiple patterning are some of the new techniques being used to improve the resolution of 193 nm lithography (Klimeck et al., 2008). In the meantime, researchers are looking into alternatives to UV lithography, such as electron beam lithography, X-ray lithography, extreme ultraviolet (UV) lithography, and ion projection lithography. Extreme UV lithography is in mass production use as of 2020 by Samsung.

Polymer

A polymer is a substance or material made up of very big molecules, or macromolecules, that are made up of many repeating subunits (Greek poly-, “many” + -mer, “part”). Both manufactured and natural polymers play crucial and pervasive roles in everyday life due to their wide range of characteristics. Polymers include everything from common synthetic plastics like polystyrene to biopolymers like DNA and proteins, which are essential for biological structure and function. Polymers, both natural and manmade, are made by polymerizing a large number of tiny molecules called monomers (Kung and Kung, 2004).

In comparison to small molecule compounds, their huge molecular mass results in unusual physical features such as toughness, high elasticity, viscoelasticity, and a tendency to form amorphous and semicrystalline structures rather than crystals.

Jöns Jacob Berzelius created the phrase in 1833, however with a different definition from the contemporary IUPAC definition. Hermann Staudinger developed the modern concept of polymers as covalently bound macromolecular structures in 1920 and spent the next decade gathering experimental evidence to support his claim.

Polymers are researched in polymer science (which includes polymer chemistry and physics), biophysics, and materials science and engineering, among other topics. Polymer science has traditionally focused on products that result from the covalent chemical bonding of repeating units. Supramolecular polymers made by non-covalent linkages are a rapidly growing field. Latex rubber polyisoprene is an example of an organic polymer, while Styrofoam polystyrene is an example of a synthetic polymer (Kaur et al., 2014). Almost all biological macromolecules —i.e., proteins (polyamides), nucleic acids (polynucleotides), and polysaccharides—are completely polymeric or contain a substantial proportion of polymeric components in biological situations.

There are two types of polymers: naturally occurring and synthetic or manmade polymers:

- **Natural:** For ages, natural polymeric materials like hemp, shellac, amber, wool, silk, and natural rubber have been employed. Other natural polymers, such as cellulose, the major component of wood and paper, are available.
- **Synthetic:** Polyethylene, polypropylene, polystyrene, polyvinyl chloride, synthetic rubber, phenol-formaldehyde resin (or Bakelite), neoprene, nylon, polyacrylonitrile, PVB, silicone, and many other synthetic polymers are listed in roughly order of international demand. Every year, around 330 million tons of these polymers were produced in 2015.

Typically, the continuously connected backbone of a polymer used to make plastics is made up of carbon atoms. Polyethylene ('polythene' in British English) is a basic example of a repeat unit or monomer whose repeat unit is ethylene. Many additional structures exist; for example, silicon is used to make silicones, examples being Silly Putty and waterproof plumbing sealant (Kandel et al., 2013). Oxygen is also commonly present in polymer backbones, such as those of polyethylene glycol, polysaccharides (in glycosidic bonds), and DNA (in phosphodiester bonds) (Figure 42).

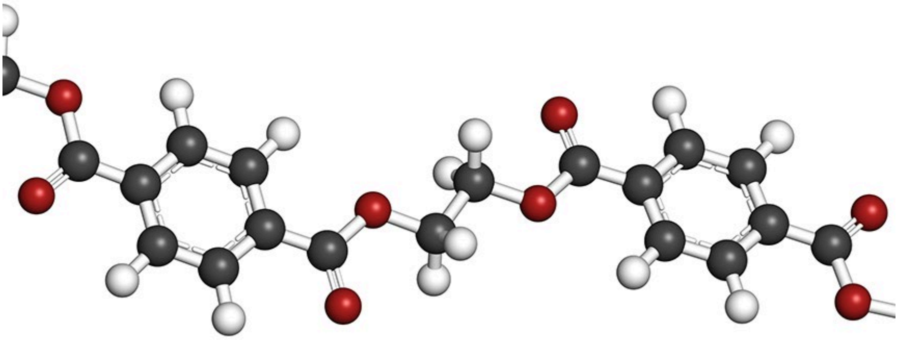


Figure 42. Polymers, whether artificial (such as the plastic shown) or natural, are made of repeating chains of smaller chemical units. Here, carbon atoms are shown as black, oxygen as red and hydrogen as white.

Source: https://www.sciencenewsforstudents.org/article/explainer-what-are-polymers.

Positional Synthesis

The design (synthesis) of a four-bar mechanism that guides a machine component, usually a tool or end-effector, through a number of positions is frequently of engineering relevance.

When the machine component is a four-bar coupler, the synthesis is commonly referred to as Position Synthesis.

The positions of the coupler can be determined using drafting aids on a drawing board and maths. When we employ Constraint-Based Sketch Tools, on the other hand, we can get fantastic insights into the design process, especially when we need to locate four or five different placements. We may also learn about Circle Point Curves (Cubic of Stationary Curvature), Centre Point Curves, and Burmester Points using the tools (Huang et al., 2010).

Protein Design

Protein design is the process of creating new protein molecules with the goal of creating new activities, behaviors, or functions while also improving our understanding of how proteins work. Proteins can be created from the ground up (de novo design) or by calculating variations of a known protein structure and sequence (termed protein redesign). Rational protein design methods predict how proteins will fold into specified shapes based on their sequences. Experiments using peptide synthesis, site-directed mutagenesis, or artificial gene synthesis can subsequently be used to validate the anticipated sequences.

The concept of rational protein design has been around since the mid-1970s. However, in recent years, there have been numerous examples of successful rational design of water-soluble and even transmembrane peptides and proteins, thanks in part to a better understanding of the various factors that contribute to protein structure stability and the development of more efficient computational methods.

The goal of rational protein design is to predict which amino acid sequences will fold into which protein structure. Despite the fact that the number of potential protein sequences grows exponentially with the length of the protein chain, only a small percentage of them fold accurately and fast to one native state (Gunasekaran et al., 2014). Within this category, protein design entails identifying unique sequences. A protein's native state is the chain's structural free energy minimum. As a result, protein design entails looking for sequences with the desired structure as a free energy minimum. It is, in some ways, the polar opposite of protein structure prediction.

A tertiary structure is given in design, and a sequence that will fold to it is found. As a result, it is also known as inverse folding. Protein design then becomes an optimization problem: a scoring criterion is used to select an optimized sequence that will fold into the desired structure.

Protein design is used to create new enzymes, which has a wide range of bioengineering and biological applications. In general, creating a protein structure differs from designing an enzyme since enzymes must account for a large number of states in the catalytic process. However, protein design is a prerequisite of de novo enzyme design because, at the very least, the design of catalysts requires a scaffold in which the catalytic mechanism can be inserted.

One of the most desirable uses for protein design is for biosensors, proteins that will sense the presence of specific compounds. Some attempts in the design of biosensors include sensors for unnatural molecules including TNT. More recently, Kuhlman and coworkers designed a biosensor of the PAK1 (Gupta, 2011).

Protein Engineering

The process of producing useful or valuable proteins is known as protein engineering. It is a relatively new field, with a lot of work being done to better understand protein folding and recognize protein design principles. It is also a market for goods and services, with a projected worth of $168 billion by 2017.

Protein engineering can be divided into two categories: rational protein design and directed evolution. These approaches are not mutually incompatible; in fact, researchers frequently use both. Protein engineering's capabilities may be substantially expanded in the future as more precise understanding of protein structure and function, as well as breakthroughs in high-throughput screening, become available. Eventually, even unnatural amino acids may be included, via newer methods, such as expanded genetic code, that allow encoding novel amino acids in genetic code.

Top7, a protein with a unique fold, and sensors for unnatural compounds were designed using computational approaches. Rilonacept, a medication developed from fusion proteins, has been approved by the Food and Drug Administration (FDA) to treat cryopyrin-associated periodic syndrome (Farokhzad and Langer, 2009).

The change of cofactor specificity of Candida boidinii xylose reductase was effectively engineered using another computer method, IPRO. Proteins are redesigned via iterative protein redesign and optimization (IPRO) to increase or give selectivity to native or novel substrates and cofactors. This is accomplished by randomly perturbing the structure of proteins around specific design positions, selecting the lowest energy rotamer combination, and testing whether the new design has a lower binding energy than previous designs.

Complex properties of a highly ordered nano-protein assembly were also engineered via computational-aided design. The model protein in this study is *E. coli* bacterioferritin (EcBfr), a protein cage that naturally exhibits structural instability and partial self-assembly activity by populating two oligomerization stages.

This protein features a smaller-than-average dimeric interface on its two-fold symmetry axis, according to computational research and comparisons to homologs, owing to the presence of an interfacial water pocket centered on two water-bridged asparagine residues. A semi-empirical computational method is used to visually examine the energy differences of the 480 potential mutations at the dimeric interface relative to the wild type EcBfr in order to study the feasibility of engineering EcBfr for enhanced structural stability. The water-bridged asparagines are also found in this computer investigation.

Circular dichroism and transmission electron microscopy show that swapping these two asparagines with hydrophobic amino acids causes proteins to fold into alpha-helical monomers and assemble into cages. Thermal and chemical denaturation demonstrate that all altered proteins have enhanced stability, as predicted by the computations. Both size exclusion chromatography and native gel electrophoresis reveal that one of the three mutations shifts the population in favor of the higher-order oligomerization state in solution (Doubleday, 2007).

Proximal Probes

A family of devices capable of fine positional control and sensing, including scanning tunneling and atomic force microscopes (AFMs); an enabling technology for nanotechnology.

Proximal Probe Microscopes are proving to be effective tools for advancing nanotechnology and nanoscience. A raster motion is used to move a nanoscopic probe across a surface in a probe microscope. The three-dimensional motion of the probe, and thus a three-dimensional depiction of the surface, is displayed on a computer screen to create a surface topographic image. Proximal probe microscopes provide quantitative height information in addition to the normal magnified picture of a surface that regular microscopes offer.

The probe is positioned near a surface in an AFM, and various mechanical properties can be measured. Mechanical qualities like surface hardness and elasticity, for example, are assessed by tracking the mechanical interactions between the probe and the sample's surface. The probe is vibrated above the surface in one technique, and the phase and amplitude of the probe's vibration are determined by the surface's mechanical properties (Ehdaie, 2007).

Sharp tips are used in proximal probe techniques, which are brought within a tiny distance of a sample to be probed by a stepper motor. The mechanical, electrical, magnetic, optical, or thermal interactions of these probe tips with the sample can be utilized to probe the sample's attributes locally and regulate the separation between tip and sample surface. If a particular type of interaction has a large distance dependence, the distance control predicated on that interaction is extremely sensitive to minor changes in tip-sample separation.

The surface contours can be tracked with great accuracy by scanning the probe tip across the sample surface while maintaining the interaction strength constant using a feedback loop. A three-dimensional image of the sample surface is obtained by measuring the vertical position of the tip as a function of the lateral position (Lakhal and Wood, 2011). Piezoelectric drives can be used to move the tip both laterally and vertically with regard to the sample surface with subatomic accuracy. Proximal probe techniques, unlike electron microscopy and vacuum-based surface analytical methods, can be used in air and liquids as well as in vacuum.

As a result, proximal probe techniques have a lot of potential for investigating solid-liquid interfaces or biological specimens in vivo. Furthermore, proximal probe techniques can be used at a wide range of temperatures (from millikelvin to more than 1,000 K) and in harsh environments (e.g., in high magnetic fields or high-pressure conditions). Nevertheless, the most appealing aspect of proximal probe approaches is that they combine ultrahigh spatial resolution (down to the atomic scale) with high-resolution spectroscopic observations to extract extensive information about the sample's physical, chemical, or biological state.

The constrained size and often ill-defined condition of probe tips, as well as the low information depth of proximal probe approaches, are limiting considerations. It has also been discovered that identifying elemental species merely based on proximal probe data is difficult, despite the fact that chemical-selective imaging down to the atomic scale is now frequently done.

Phase

A phase is a chemically and physically uniform or homogeneous amount of matter that can be mechanically separated from a nonhomogeneous mixture and that may consist of a single material or a mixture of substances, according to thermodynamics. Solid, liquid, and gas (vapor) are the three fundamental phases of matter, however other phases such as crystalline, colloid, glassy, amorphous, and plasma are thought to exist. A phase change occurs when a phase in one form transforms into a different form (Doubleday, 2007).

A system is a segment of the universe that has been chosen for studying the changes that occur within it as a result of changing conditions. A system might be complex, like a planet, or very basic, like a glass of liquid. Phases are the parts of a system that are physically different and mechanically separate from the rest of the system.

A system's phases can be in a gaseous, liquid, or solid form. Strong atomic bonding and high viscosity characterize solids, culminating in a hard form. Most solids are crystalline because they have a three-dimensional periodic atomic arrangement; however, some solids (such as glass) lack this periodic pattern and are amorphous. Gases are made up of atoms that are loosely linked and have no long-range periodicity; they expand to fill any available space. Liquids have qualities that are halfway between solids and gases. A liquid's molecules are condensed like those of a solid.

Liquids have a fixed volume, but because of their low viscosity, they can change shape over time. Although a system can contain more than one solid or liquid phase, it can only include one gas phase, which must have a homogeneous composition because gas molecules mix entirely in all proportions (Figure 43).

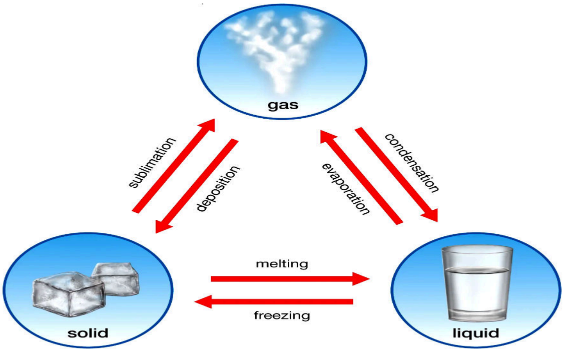


Figure 43. Phase change.

Source: https://www.britannica.com/science/phase-state-of-matter#ref52025.

Phase Diagram

A phase diagram is a sort of chart used in physical chemistry, engineering, mineralogy, and materials science to depict the parameters (pressure, temperature, volume, and so on) at which thermodynamically distinct phases (such as solid, liquid, or gaseous states) occur and coexist at equilibrium. Lines of equilibrium or phase boundaries, which refer to lines that denote conditions under which various phases can coexist at equilibrium, are common components of a phase diagram. Phase transitions happen along equilibrium lines. Metastable phases, despite their ubiquitous occurrence, are not indicated in phase diagrams since they are not equilibrium phases (Ehdaie, 2007).

On phase diagrams, triple points occur where lines of equilibrium intersect. The term "triple point" refers to a situation in which three distinct phases can coexist. The water phase diagram, for instance, has a triple point, which corresponds to the single temperature and pressure at which solid, liquid, and gaseous water can coexist in stable equilibrium (273.16 K and a partial vapor pressure of 611.657 Pa).

The solidus is the lowest temperature at which a substance will remain solid. The liquidus is the temperature at which a substance remains liquid at all times. There may be a gap between the solidus and the liquidus; the substance within the gap is a mixture of crystals and liquid (like a "slurry"). Working fluids are often categorized on the basis of the shape of their phase diagram (Figure 44).

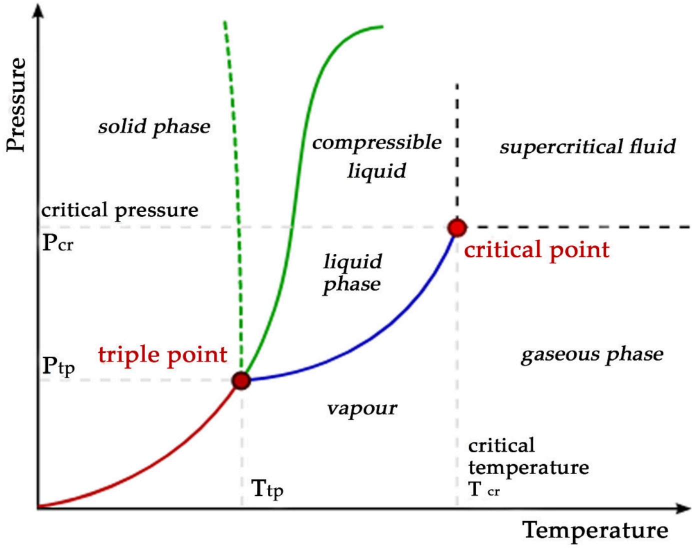


Figure 44. Phase diagram: In this phase diagram, which is typical of most substances, the solid lines represent the phase boundaries. The green line marks the freezing point (or transition from liquid to solid), the blue line marks the boiling point (or transition from liquid to gas), and the red line shows the conditions under which a solid can be converted directly to a gas (and vice-versa). The dotted green line is meant to replace the solid green line in the corresponding phase diagram of water. It illustrates water's anomalous behavior.

Source: https://courses.lumenlearning.com/boundless-chemistry/chapter/phase-diagrams/.

Phase Transport

The Phase Transport and Phase Transport in Porous Media interfaces are designed to investigate the transport of several immiscible fluid, gas, or (dispersed) solid phases in free-flow or via porous media. The interfaces solve for the averaged volume fractions (also known as saturation in a porous medium) of the phases rather than the interfaces between them. The macroscopic mass conservation equations of each phase are used to create both interfaces. The effects of tiny (or pore-scale) interfaces between the phases in a porous media can be taken into consideration using capillary pressure functions.

The exchange of mass, energy, charge, momentum, and angular momentum between observable and researched systems is the subject of transport phenomena research in engineering, physics, and chemistry. While it draws on a variety of subjects, such as continuum mechanics and thermodynamics, it focuses heavily on the topics' commonalities. The mathematical frameworks of mass, momentum, and heat transfer are all quite similar, and the similarities are used in the study of transport phenomena to draw deep mathematical linkages that frequently provide very valuable tools in the analysis of one subject that are directly derived from the others (Farokhzad and Langer, 2009).

The fundamental analysis in all three subfields of mass, heat, and momentum transfer is frequently based on the simple assumption that the system and its surroundings must conserve the total sum of the quantities being studied. As a result, the various processes that contribute to transportation are examined separately, with the understanding that the aggregate of their contributions must equal zero. This principle can be used to calculate a variety of important quantities. A common use of transport analysis in fluid mechanics is to calculate the velocity profile of a fluid passing through a rigid volume.

Transportation phenomena can be found in all engineering areas. The fields of process, chemical, biological, and mechanical engineering are some of the most notable types of transport analysis in engineering, but the subject is a fundamental component of the curriculum in all disciplines that deal with fluid mechanics, heat transfer, and mass transfer in any way. It is currently regarded as an engineering discipline in the same way as thermodynamics, mechanics, and electromagnetism are (Gupta, 2011).

All agents of physical change in the cosmos are included in transport phenomena. Furthermore, they are thought to be fundamental building pieces that contributed to the creation of the cosmos and are responsible for the survival of all life on Earth. The scope of this chapter is, however, limited to the link between transportation phenomena and artificially designed systems.

Photoluminescence

After the absorption of photons, photoluminescence (abbreviated as PL) is light emission from any form of materials (electromagnetic radiation). It is one of many types of luminescence (light emission) that is triggered by photoexcitation (photons that excite electrons in an atom to a higher energy level), therefore the prefix photo-. Following excitation, numerous relaxation processes occur, resulting in the re-radiation of other photons.

Time intervals between absorption and emission can range from milliseconds for phosphorescence processes in molecular systems to femtoseconds for emission involving free-carrier plasma in inorganic semiconductors and under special circumstances delay of emission may even span to minutes or hours (Figure 45).

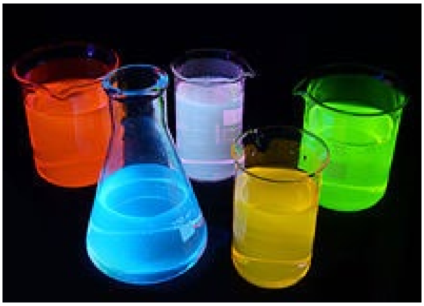


Figure 45. Fluorescent solutions under UV light. Absorbed photons are rapidly re-emitted under longer electromagnetic wavelengths.

Source: https://en.wikipedia.org/wiki/Photoluminescence.

Various factors, such as the energy of the stimulating photon in relation to the emission, can be used to classify photoluminescence processes. Resonant excitation describes a condition in which photons of a specific wavelength are absorbed and then swiftly re-emitted as equivalent photons. Resonance fluorescence is a term used to describe this phenomenon. This process involves electrons but no substantial internal energy changes involving molecular characteristics of the chemical substance between absorption and emission for materials in solution or in the gas phase (Klimeck et al., 2008).

Secondary emission in crystalline inorganic semiconductors with an electronic band structure can be more complicated because events can consist of both coherent and incoherent contributions, such as resonant Rayleigh scattering, where a fixed phase relation with the driving light field is held (i.e., energetically elastic processes with no losses) (or inelastic modes where some energy channels into an auxiliary loss mode).

The latter come from radiative recombination of excitons, Coulomb-bound electron-hole pair states in solids, for example. Quantum optical correlations may also be visible in resonance fluorescence.

Photoluminescence is a useful tool for determining the purity and crystalline quality of semiconductors like GaN and InP, as well as quantifying the level of disorder in a system.

TRPL (time-resolved photoluminescence) is a method for measuring the decay in photoluminescence with respect to time after the sample has been excited with a light pulse. The minority carrier lifetime of III-V semiconductors such as gallium arsenide can be measured using this technique (GaAs).

Piezoelectric

Piezoelectricity is the electric charge that builds up in certain solid materials, such as crystals and ceramics, as well as biological matter like bone, DNA, and different proteins, in reaction to mechanical stress. The term piezoelectricity refers to the generation of electricity from pressure and latent heat. It comes from the Greek words piezein, which means “to squeeze” or “to press,” and lektron, which means “amber,” an old source of electric charge (Kung and Kung, 2004).

In crystalline materials with no inversion symmetry, the piezoelectric effect is caused by a linear electromechanical connection between the mechanical and electrical states.

The piezoelectric effect is a reversible phenomenon, and materials that exhibit it also exhibit the reverse piezoelectric effect, which is the internal creation of mechanical strain in response to an applied electrical field. When the static structure of lead zirconate titanate crystals is distorted by around 0.1% of its original dimension, detectable piezoelectricity is generated. When an external electric field is added, those identical crystals will change around 0.1% of their static dimension. Ultrasound waves are created via the inverse piezoelectric effect (Figure 46).

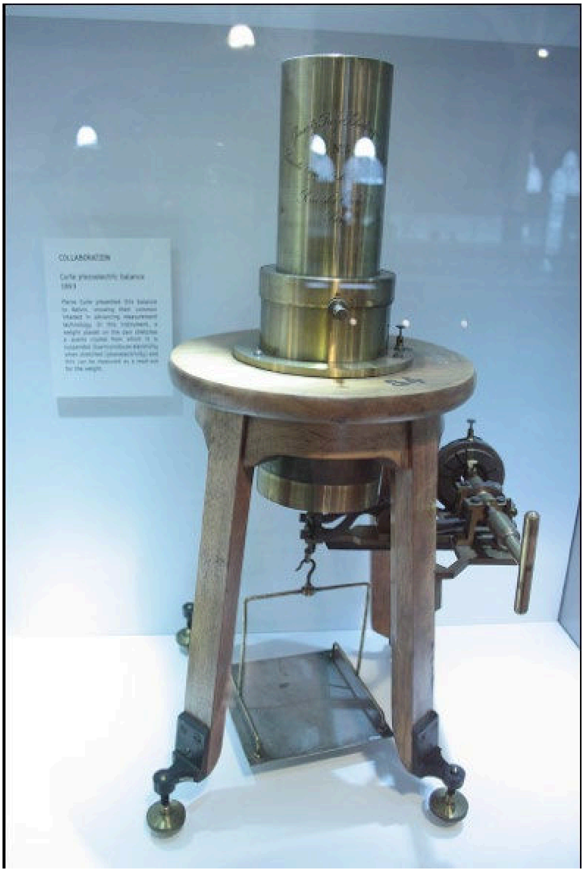


Figure 46. Piezoelectric balance presented by Pierre Curie to Lord Kelvin, Hunterian Museum, Glasgow.

Source: https://en.wikipedia.org/wiki/Piezoelectricity#/media/File:Piezoelectric_balance_presented_by_Pierre_Curie_to_Lord_Kelvin,_Hunterian_Museum,_Glasgow.jpg.

Polymerase Chain Reaction (PCR)

Polymerase chain reaction (PCR) is a widely used method for rapidly producing millions to billions of copies (full or partial copies) of a specific DNA sample, allows researchers to take a small sample of DNA and amplify it (or a portion of it) to a big enough amount to investigate in depth. Kary Mullis, an American scientist at Cetus Corporation, devised PCR in 1983. Many processes used in genetic testing and research, such as the analysis of ancient DNA samples and the detection of infectious organisms, rely on it. In a series of temperature changes, duplicates of very small amounts of DNA sequences are exponentially amplified using PCR (Gunasekaran et al., 2014).

PCR is today a widely used and frequently indispensable technology in medical laboratory research, with applications ranging from biomedical research to criminal forensics.

Thermal cycling is used in the majority of PCR techniques. Thermal cycling involves repeatedly heating and cooling reactants to allow for various temperature-dependent processes, such as DNA melting and enzyme-driven DNA replication. Primers (short single-strand DNA fragments known as oligonucleotides that have a complementary sequence to the target DNA region) and a DNA polymerase are the two major chemicals used in PCR.

The two strands of the DNA double helix are physically split at a high temperature in the first stage of PCR, a process known as nucleic acid denaturation. The temperature is decreased in the second stage, and the primers bind to the corresponding DNA sequences. The two DNA strands then serve as templates for DNA polymerase, which uses free nucleotides as building blocks to create a new DNA strand enzymatically. As the PCR process advances, the DNA created is employed as a replication template, triggering a chain reaction in which the original DNA template is exponentially amplified.

A heat-stable DNA polymerase, such as Taq polymerase, which was originally obtained from the thermophilic bacteria Thermus aquaticus, is used in almost all PCR applications. The high temperatures of the denaturation stage would denature the polymerase if it was heat-susceptible. Previously, DNA polymerase had to be manually introduced to each cycle, which was a time-consuming and costly operation (Kaur et al., 2014).

DNA cloning for sequencing, gene cloning and manipulation, gene mutagenesis; building of DNA-based phylogenies or functional study of genes; diagnosis and monitoring of genetic abnormalities; amplification of ancient DNA; analysis of genetic fingerprints for DNA profiling (for example, in forensic science and parentage testing); and detection of pathogens in nucleic acid tests for the diagnosis of infectious diseases, are some of the applications of the technology.

Polymorphism

Polymorphism is the existence of two or more distinctly different morphs or forms in a population of a species, often known as alternative phenotypes. To be categorized as such, morphs must share the same environment and be part of a panmictic population at the same time (one with random mating).

Simply put, polymorphism occurs when a trait on a gene has two or more possible variants. When it comes to a jaguar's skin coloration, for example, there are several options: light morph or dark morph. Polymorphism refers to the fact that this gene has multiple potential variations.

If the jaguar only has one potential phenotype for that gene, it is said to be "monomorphic." Monomorphic means there is just one potential skin color for a jaguar, for example.

The term polyphenism refers to the fact that the various forms are all derived from the same gene. Genetic polymorphism is a phrase used by geneticists and molecular biologists to explain some mutations in the genotype, such as single nucleotide polymorphisms, that may or may not match to a phenotype but always correlate to a genetic branch (Kandel et al., 2013).

Polymorphism is a natural phenomenon that is linked to biodiversity, genetic variety, and adaptation. Polymorphism is most commonly used to maintain variety of form in a population that lives in a diverse environment. Sexual dimorphism, which occurs in many creatures, is the most typical example. Mimetic forms of butterflies (see mimicry) and human hemoglobin and blood types are more examples.

Polymorphism, like any other trait of a species, results from evolutionary processes, according to evolutionary theory.

Natural selection modifies it and it is heritable. A person's genetic makeup allows for different morphs in polyphenism, and the switch mechanism that decides which morph is revealed is situational. The morph is determined by the genetic makeup in genetic polymorphism.

Polymorphism also refers to the presence of more than two physically and functionally distinct types of individuals, known as zooids, within the same organism. Cnidarians are known for having this trait. Obelia, for example, has feeding individuals called gastrozooids, gonozooids, blastostyles, and free-living or sexually reproducing individuals the medusae.

Proteins

Proteins are huge biomolecules and macromolecules that are made up of one or more long chains of amino acids. Proteins play a variety of roles in organisms, including catalyzing metabolic events, DNA replication, responding to stimuli, giving cells and organisms structure, and moving materials from one place to another. Proteins differ primarily in their amino acid sequence, which is governed by their genes' nucleotide sequence and usually culminates in protein folding into a specific 3D structure that dictates its activity (Huang et al., 2010).

A polypeptide is a linear chain of amino acid residues. At least one lengthy polypeptide can be found in a protein. Short polypeptides (less than 20–30 residues) are often referred to as peptides or oligopeptides and are rarely considered proteins. Peptide bonds and neighboring amino acid residues bind the individual amino acid residues together. A gene's sequence, which is encoded in the genetic code, determines the amino acid residue sequence in a protein. In most species, the genetic code specifies 20 normal amino acids; but, in some archaea, the genetic code might include selenocysteine and pyrrolysine.

The residues in a protein are frequently chemically transformed by post-translational modification shortly after or even during synthesis, altering the physical and chemical characteristics, folding, stability, activity, and, ultimately, the function of the proteins. non-peptide groups, often known as prosthetic groups or cofactors, are connected to some proteins. Proteins can also collaborate to perform a specific job, and they frequently form stable protein complexes.

Proteins only persist for a short time once they are created, and then they are destroyed and recycled by the cell's machinery through the protein turnover process. The longevity of a protein is measured in terms of its half-life, which can vary greatly. In mammalian cells, they can live for minutes or years, with an average lifespan of 1–2 days. Proteins that are abnormal or misfolded degrade more quickly, either because they are targeted for destruction or because they are unstable (Lakhal and Wood, 2011).

Proteins, like other biological macromolecules like polysaccharides and nucleic acids, are vital elements of organisms that play a role in nearly every function within cells. Enzymes are proteins that catalyze biological reactions and are essential for metabolism.

Actin and myosin in muscle and the proteins in the cytoskeleton, which constitute a scaffolding framework that keeps cells in shape, are examples of proteins with structural or mechanical activities. Cell signaling, immunological responses, cell adhesion, and the cell cycle all require other proteins. Proteins are required in the diet of animals in order to give vital amino acids that cannot be produced. Proteins are broken down during digestion and used in the metabolism.

Proteins can be separated from other cellular components using a range of techniques, including ultracentrifugation, precipitation, electrophoresis, and chromatography; the advent of genetic engineering has made a number of purifications approaches available. Immunohistochemistry, site-directed mutagenesis, X-ray crystallography, nuclear magnetic resonance, and mass spectrometry are all common methods for studying protein structure and function.

Proteomics

Proteomics is the study of proteins on a vast scale. Proteins serve a variety of tasks in living organisms. An organism's or system's proteome is the total set of proteins it produces or modifies. Proteomics allows an ever-increasing number of proteins to be identified. This varies over time and depending on the specific requirements, or stresses, that a cell or organism is subjected to (Klimeck et al., 2008). Proteomics is an interdisciplinary field that has tremendously benefited from the genetic data generated by different genome studies, particularly the Human Genome Project. It is an important component of functional genomics and involves the research of proteomes from the overall level of protein composition, structure, and activity.

Proteomics refers to the large-scale experimental investigation of proteins and proteomes in general, but it is frequently used to refer to protein purification and mass spectrometry in particular.

After the invention of the two-dimensional gel and mapping of proteins from the bacterium *Escherichia coli* in 1975, the first studies of proteins that may be considered proteomics began (Doubleday, 2007).

The term "proteome" is a combination of the word's "protein" and "genome." Marc Wilkins, then a PhD student at Macquarie University, created the term in 1994 when the university established the first specialized proteomics laboratory in 1995.

Q

Quantum Dot

According to quantum physics, quantum dots (QDs) are semiconductor particles a few nanometers in size with optical and electrical properties that differ from bigger particles. They are a big deal in nanotechnology. When UV light illuminates QDs, an electron in the quantum dot can be stimulated to a higher energy state. This mechanism corresponds to an electron transitioning from the valence band to the conductance band in a semiconducting quantum dot. The excited electron can return to the valence band and release its energy through light emission. The image on the right depicts this light production (photoluminescence).

When band structure in QDs is no longer a good definition, the hue of that light is determined by the energy difference between the conductance band and the valence band, or the transition between discretized energy states.

Nanoscale semiconductor materials, in materials science terms, tightly contain either electrons or electron holes. QDs are frequently referred to as artificial atoms, stressing their singularity, which includes bonded, discrete electronic states similar to those seen in natural atoms or molecules. The electronic wave functions of QDs were found to be similar to those of actual atoms.

An artificial molecule can be created by linking two or more of these QDs, displaying hybridization even at ambient temperature (Contreras et al., 2017).

QDs are a hybrid of bulk semiconductors and discrete atoms or molecules in terms of characteristics. They have different optoelectronic properties depending on their size and shape. Longer wavelengths, such as orange or red, are emitted by larger QDs having a diameter of 5–6 nm. Shorter wavelengths are emitted by smaller QDs (2–3 nm), resulting in colors like blue and green. The individual hues, on the other hand, differ depending on the QD's actual composition.

Single-electron transistors, solar cells, LEDs, lasers, single-photon sources, second-harmonic generation (SHG), quantum computing, cell biology research, microscopy, and medical imaging are all possible applications for QDs. Because of their small size, some QDs can be suspended in solution, which could lead to applications in inkjet printing and spin-coating. In Langmuir-Blodgett (LB) thin films, they have been employed. These processing approaches result in semiconductor production procedures that are less expensive and time-consuming.

QDs can be made in a variety of methods. Colloidal synthesis, self-assembly, and electrical gating are all possibilities (Figure 47).

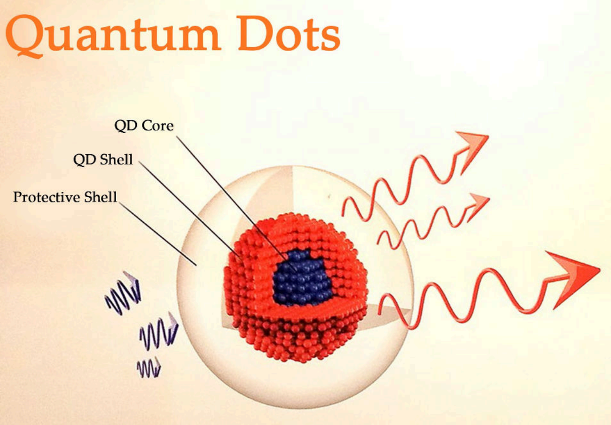


Figure 47. Quantum dots are semiconductor particles having a diameter of 2–10 nm and a wavelength of 2–10 nm. They are so termed because quantum effects play a crucial role in their light-emitting properties due to their nanoscale size. Quantum dots use this method to generate light: when exposed to an external stimulus, some of the dot material's electrons absorb enough energy to break free from their atomic orbit. This produces a conductance area in which

electrons can effectively conduct electricity by moving through the substance. Energy is released in the form of light as these electrons return to atomic orbit, the color of which depends on the quantity of energy released.

Source: https://www.edn.com/quantum-dots-explained/.

Colloidal semiconductor nanocrystals are made from solutions in the same way that standard chemical operations are done. The primary distinction is that the product does not precipitate as a bulk solid and does not remain dissolved. The precursors breakdown when the solution is heated to a high temperature, forming monomers, which subsequently nucleate and create nanocrystals. Temperature has an important role in determining the best circumstances for nanocrystal development. It must be high enough to allow for rearrangement and annealing of atoms during the synthesis process while being low enough to promote crystal growth.

Under certain circumstances, QDs may constitute a threat to human health and the environment. Notably, investigations on quantum dot toxicity have primarily focused on cadmium-containing particles, with no evidence of toxicity in animal models following physiologically relevant dose. QD toxicity may be caused by a variety of factors, including their physicochemical properties (size, shape, composition, surface functional groups, and surface charges) and their surroundings, according to in vitro studies based on cell cultures (Chauhan et al., 2012). It is difficult to assess their potential toxicity because there are so many variables to consider, such as QD size, charge, concentration, chemical composition, capping ligands, and on their oxidative, mechanical, and photolytic stability.

Quantum Confinement Effect

When the particle's size is too small to be equivalent to the electron's wavelength, the quantum confinement effect occurs. To comprehend this phenomenon, we must first dissect the terms quantum and confinement. The term confinement refers to restricting the mobility of a randomly moving electron to specified energy levels (discreteness), while quantum refers to the atomic realm of particles. As the size of a particle shrinks until it reaches the nanoscale, the constraining dimension shrinks, making the energy levels distinct, which increases or widens the bandgap, and therefore the bandgap energy.

When dealing with quantum confinement, it may be easier to deal with the charge carrier's Bohr radius. If the quantum box/dot is smaller, confinement occurs, resulting in a change from continuous to discrete energy levels. It should be noted that the term charge carrier can apply to an electron, as previously stated, or to an exciton (electron-hole quasiparticle) in materials such as semiconductors.

A quantum dot's physical properties do not appear to be influenced by quantum confinement; nonetheless, their optical absorption and emission can be modified using the quantum size effect. The particle in a sphere is a good model for this.

A particle in a box model can be used to understand quantum confinement. If a particle like an electron is restricted to a box, its energy cannot remain random or continuous, hence it is defined in terms of discrete energy levels. When electrons are contained in a solid matrix, the energy gap widens. It indicates that if the solid is a semiconductor, the bandgap of the semiconductor will grow as the particle size of the semiconductor drops to a nano level, but it also depends on the material's properties, particularly the Bohr radius (Chen and Yada, 2011).

As a result, if the size of the nanocrystal is large, as in the case of semiconductors from groups 2 and 6, The bandgap will drop as the constituent atoms of the semiconductor become heavier, as seen in nano calcium oxide, where the bandgap decreases from 7.1 eV to 4.8 eV. However, when the size of the object shrinks, the energy and gap grow. This is based on the well-known particle energy formula E = n2h2/8ma2, where m is the particle's mass and an is the box's dimension.

Quantum confinement is a unique property of QDs in that it changes the density of states near the band edge as the density of electronic states changes. The optical lines shift as a product of the sphere's radius due to size quantization of exciton states. The energy of the particles increases in potential as their size decreases, resulting in a short-wave shift in absorption. QDs are nano-sized particles in which electrons are trapped inside fixed parameters. When changes in atomic structure occur as a result of reducing the size of a material, the quantum confinement effect is observed. As a result, the bandgap is tuned, and the energy levels shift from continuous to discrete levels. Doping the QDs also changes their optoelectronic properties.

R

Raman Spectroscopy

Raman spectroscopy is a spectroscopic technique used to discern the vibrational modes of molecules, while it may also detect rotational and other low-frequency modes of systems. In chemistry, Raman spectroscopy is often employed to generate a structural fingerprint that may be used to identify compounds (Doubleday, 2007).

Raman spectroscopy relies on Raman scattering, which is the inelastic scattering of photons. A monochromatic light source is employed, which is commonly a laser in the visible, near-infrared, or near-ultraviolet (UV) spectrum, though X-rays can also be used. The energy of the laser photons is pushed up or down as the laser light interacts with molecular vibrations, phonons, or other excitations in the system. The energy shift reveals information about the system's vibrational modes. Infrared spectroscopy usually produces comparable but complementary results (Ehdaie, 2007).

A laser beam is usually used to light a sample. A lens collects electromagnetic radiation from the lit spot and sends it through a monochromator. A notch filter, edge pass filter, or bandpass filter is used to filter out elastic scattered radiation at the wavelength corresponding to the laser line (Rayleigh scattering), while the rest of the collected light is dispersed onto a detector (Figure 48).

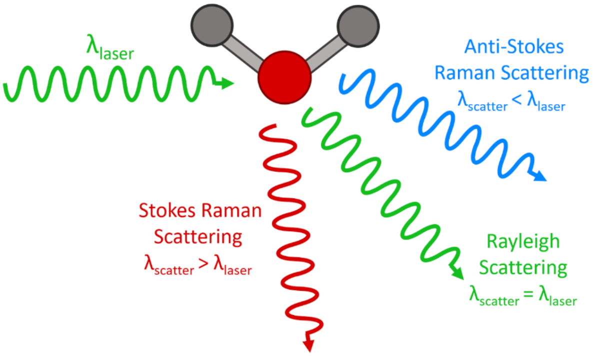

λ_{laser}
Anti-Stokes Raman Scattering
$\lambda_{scatter} < \lambda_{laser}$
Stokes Raman Scattering
$\lambda_{scatter} > \lambda_{laser}$
Rayleigh Scattering
$\lambda_{scatter} = \lambda_{laser}$

Figure 48. Three types of scattering processes that can occur when light interacts with a molecule.

Source: https://www.edinst.com/blog/what-is-raman-spectroscopy/.

Because spontaneous Raman scattering is often relatively weak, distinguishing the weak inelastically scattered light from the powerful Rayleigh scattered laser light has been a major challenge in collecting Raman spectra for many years (referred to as “laser rejection”). To achieve a high level of laser rejection in the past, Raman spectrometers used holographic gratings and numerous dispersion stages. Photomultipliers were once the preferred detectors for dispersive Raman setups, resulting in lengthy acquisition times. Modern instrumentation, on the other hand, almost always uses notch or edge filters for laser rejection. Dispersive single-stage spectrographs (axial transmissive (AT) or Czerny–Turner (CT) monochromators) paired with CCD detectors are most common although Fourier transform (FT) spectrometers are also common for use with NIR lasers (Seil and Webster, 2012).

The term “Raman spectroscopy” usually refers to vibrational Raman spectroscopy that uses laser wavelengths that are not absorbed by the material. Surface-enhanced Raman, resonance Raman, tip-enhanced Raman, polarized Raman, stimulated Raman, transmission Raman, spatially-offset Raman, and hyper Raman are all examples of Raman spectroscopy. The polarizability of electrons in a molecule corresponds with the degree of the Raman Effect. A photon stimulates the sample in this type of inelastic light scattering. Before the photon is emitted, this excitation puts the molecule into a virtual energy state for a short time. Inelastic scattering means that the energy of the emitted photon is of either lower or higher energy than the incident photon. After the scattering event, the sample is in a different rotational or vibrational state.

The energy of the emitted photon is either lower or higher than the energy of the incident photon in inelastic scattering. The sample is in a changed rotational or vibrational state after the scattering event. A change in electric dipole-electric dipole polarizability with regards to the vibrational position corresponding to the rovibronic stat is required for a molecule to display a Raman Effect. The intensity of the Raman scattering is proportional to this polarizability change. Therefore, the Raman spectrum (scattering intensity as a function of the frequency shifts) depends on the rovibronic states of the molecule.

Reduction

Any of a range of chemical reactions in which the number of electrons involved with an atom or group of atoms is raised is referred to as reduction. The electrons taken up by the reduced molecule are provided by another substance, which is oxidized as a result.

Any chemical process in which the oxidation number of a participating chemical species changes is known as an oxidation-reduction reaction, or redox reaction. The word refers to a broad range of processes. Many oxidation-reduction reactions are as frequent and familiar as fire, metal corrosion and dissolving, fruit browning, and essential life functions like breathing and photosynthesis.

Most oxidation-reduction (redox) reactions involve the transfer of oxygen atoms, hydrogen atoms, or electrons, with all three processes sharing two important characteristics: (i) they are coupled—that is, a reciprocal reduction occurs in any oxidation reaction; and (ii) they involve a characteristic net chemical change—that is, an atom or electron moves from one unit of matter to another. In examples of the three most prevalent types of oxidation-reduction reactions, both reciprocity and net change are shown (Figure 49).

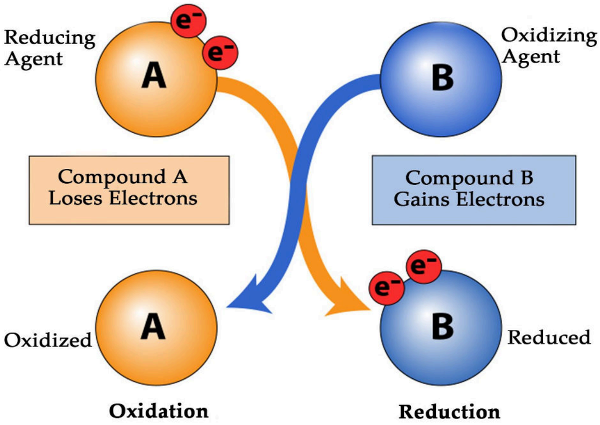


Figure 49. Oxidation-reduction.

Source: https://www.shutterstock.com/search/oxidation+reduction.

The following description of redox processes provides no information on the method by which change occurs. The stoichiometry of the reaction, which offers the distinctive combining proportions of elements and compounds, is a thorough description of the net chemical change for a process. On the grounds of stoichiometry, reactions are classed as redox or nonredox; stoichiometric categories include oxygen-atom, hydrogen-atom, and electron transfer. Modern molecular structure theory has enabled comprehensive definitions of oxidation and reduction (Sawhney et al., 2008).

Each element's bonding characteristics are determined by the presence of a positive nucleus surrounded by negative electrons. Atoms donate, acquire, or share electrons when creating chemical bonds. This allows each atom to be assigned an oxidation number, which indicates how many of its electrons are capable of establishing bonds with other atoms. The bonding pattern within a molecule is calculated based on the specific atoms in a molecule and their known bonding capacities, and each atom is viewed as being in a certain oxidation state, indicated by an oxidation number.

Examples of reduction: The H+ ions, with an oxidation number of +1, are reduced to H_2, with an oxidation number of 0, in the reaction:

$Zn(s) + 2H^{+}(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

Another simple example is the reaction between copper oxide and magnesium to yield copper and magnesium oxide:

$CuO + Mg \rightarrow Cu + MgO$

Iron rusting is a two-step process including oxidation and reduction. Iron is oxidized while oxygen is reduced. While the "oxygen" concept of oxidation and reduction makes it simple to see which species are oxidized and reduced, visualizing electrons is more difficult. Rewriting the reaction as an ionic equation is one approach to do this. Ionic compounds are copper (II) oxide and magnesium oxide, but metals are not:

$Cu^{2+} + Mg \rightarrow Cu + Mg^{2+}$

To create copper, the copper ion gains electrons and undergoes reduction. To generate the 2+ cation, magnesium undergoes oxidation by losing electrons. You can also think of it as magnesium contributing electrons to copper (II) ions, reducing them. Magnesium is a natural reducer. Copper (II) ions extract electrons from magnesium to generate magnesium ions in the meantime. The oxidizing agent is copper (II) ions.

Resist

(Technology) Something that resists or prevents a certain action; specif.: A substance applied to a surface, as of metal, or of a silicon wafer, to prevent the action on it of acid, other chemical agents, or any other process such as irradiation or deposition, which would modify the surface if not protected. The resist is usually applied or in some way formed into a pattern so that the underlying surface may be modified in a complementary pattern (Farokhzad and Langer, 2009).

A resist is a thin layer used in semiconductor manufacture to transfer a circuit layout to the semiconductor substrate it is formed on. Using lithography, a resist can be designed to create a micrometer-scale temporary mask that shields certain regions of the underlying substrate during subsequent processing stages. A viscous solution is usually utilized to create such a thin layer. Resists are usually unique blends of a polymer or its precursor, as well as other tiny molecules, that have been carefully created for a particular lithography process (Figure 50).

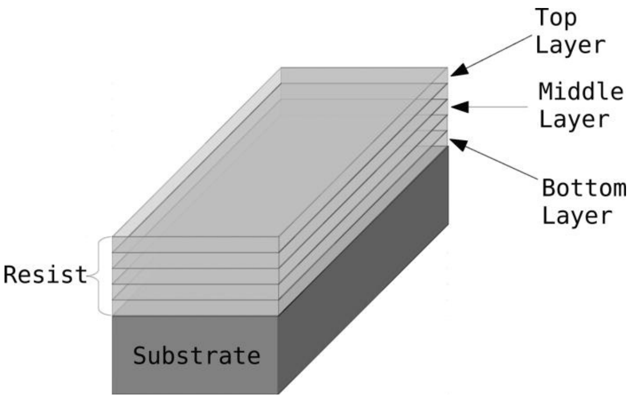


Figure 50. Resist system is modeled by multiple thin layers. In this study, the top, middle, and bottom layers are considered.

Source: https://www.researchgate.net/publication/258672272_Fast_simulation_of_stochastic_exposure_distribution_in_electron-beam_lithography/figures?lo=1.

Photoresists are resists that are used in photolithography. A photoresist (also known as a resist) is a light-sensitive substance that is used to generate a patterned coating on a surface in processes such as photolithography and photoengraving. In the electronic industry, this procedure is critical.

The method begins with the application of a light-sensitive organic substance to a substrate. Only unmasked parts of the material are exposed to light after a patterned mask is put to the surface to restrict light. The surface is subsequently treated with a developer, which is a type of solvent. In the case of a positive photoresist, light degrades the photosensitive substance, and the developer dissolves the light-exposed regions, leaving behind a coating where the mask was put.

The photosensitive substance is reinforced (either polymerized or cross-linked) by light in the case of a negative photoresist, and the developer will dissolve only the regions that were not exposed to light, leaving a coating in areas where the mask was not put.

Before applying the photoresist, a BARC coating (Bottom Anti-Reflection Coating) can be applied to prevent reflections under the photoresist and to increase the photoresist's performance at smaller semiconductor nodes.

Resist: something (such as a coating) that protects against a chemical, electrical, or physical action.

RNA (Ribonucleic Acid)

RNA (ribonucleic acid) is a complex high-molecular-weight molecule that participates in cellular protein production and, in some viruses, replaces DNA (deoxyribonucleic acid) as a carrier of genetic instructions. RNA is made up of strands of ribose nucleotides (nitrogenous bases bonded to a ribose sugar) connected by phosphodiester linkages. Adenine, guanine, cytosine, and uracil, which substitutes thymine in DNA, are nitrogenous bases in RNA. RNA's ribose sugar is a cyclical structure with five carbon atoms and one oxygen atom. The presence of a chemically reactive hydroxyl (OH) group on the second carbon group in the ribose sugar molecule makes RNA susceptible to hydrolysis.

The chemical lability of RNA, as opposed to DNA, which lacks a reactive OH group in the same place on the sugar moiety (deoxyribose), is regarded to be one of the reasons why DNA evolved to be the favored carrier of genetic information in most animals. R.W. Holley described the structure of the RNA molecule in 1965 (Sahoo and Labhasetwar, 2003).

RNA is a single-stranded biopolymer in most cases. Self-complementary sequences in the RNA strand, on the other hand, cause intrachain base-pairing and the folding of the ribonucleotide chain into complex structural shapes with bulges and helices.

The three-dimensional structure of RNA is crucial to its stability and function, as it allows biological enzymes to attach chemical groups (e.g., methyl groups) to the chain and modify the ribose sugar and nitrogenous bases in a variety of ways. Such changes allow chemical interactions to develop across remote sections of the RNA strand, resulting in complicated RNA chain contortions that further solidify the RNA structure. Molecules with insufficient structural changes and stability are easily destroyed. Modification at position 58 of the tRNA chain, for example, renders an initiator transfer RNA (tRNA) molecule without a methyl group (tRNAiMet) molecule unstable and hence nonfunctional; the nonfunctional chain is destroyed by cellular tRNA quality control mechanisms.

The three most well-known and studied kinds of RNA are messenger RNA (mRNA), tRNA, and ribosomal RNA (rRNA), all of which are found in all species. These and other forms of RNAs, like enzymes, primarily carry out biological activities. Some, on the other hand, have intricate regulatory functions in cells. RNAs play crucial roles in both normal cellular processes and illnesses due to their involvement in many regulatory mechanisms, their abundance, and their various functions.

mRNA transports genetic information from the nucleus to ribosomes, which are the sites of protein translation in the cytoplasm, in the process of protein synthesis. Ribosomes are made up of two components: rRNA and protein. The ribosomal protein subunits are produced in the nucleolus and are encoded by rRNA. They travel to the cytoplasm once fully constructed, where they "read" the code conveyed by mRNA as important regulators of translation. In mRNA, a sequence of three nitrogenous bases determines the inclusion of a certain amino acid in the protein sequence. tRNA (also known as soluble or activator RNA) molecules with fewer than 100 nucleotides transport the necessary amino acids to the ribosome where they are linked to form proteins.

RNAs are classified as coding (cRNA) or noncoding (nRNA) in addition to mRNA, tRNA, and rRNA (ncRNA). Housekeeping ncRNAs (tRNA and rRNA) and regulatory ncRNAs, which are further divided based on their size, are the two categories of ncRNAs. Small ncRNAs (sncRNAs) contain fewer than 200 nucleotides, whereas long ncRNAs (lncRNAs) have at least 200 nucleotides. MicroRNA (miRNA), small nucleolar RNA (snoRNA), small nuclear RNA (snRNA), small-interfering RNA (siRNA), and PIWI-interacting RNA are the different types of small ncRNAs (piRNA).

The relevance of miRNAs cannot be overstated. In most eukaryotes, they are around 22 nucleotides long and play a role in gene regulation. They can mute (inhibit) gene expression by binding to target mRNA and blocking translation, preventing the production of functional proteins. Many miRNAs are involved in the development of cancer and other disorders. Tumor suppressor and oncogenic (cancer-initiating) miRNAs, for example, can influence specific target genes, resulting in carcinogenesis and tumor progression (Gupta, 2011).

The piRNAs, which are about 26 to 31 nucleotides long and found in most species, are also of functional importance. They prevent transposons (jumping genes) from being transcribed in germ cells, therefore regulating their expression (sperm and eggs). The majority of piRNAs are complementary to various transposons and can target them selectively.

Circular RNA (circRNA) differs from other RNA types in that its 5′ and 3′ ends are joined to form a loop. CircRNAs are made up of multiple protein-coding genes, and some of them, like mRNA, can be used as templates for protein synthesis. They can also bind to miRNA and behave as "sponges," preventing miRNA molecules from binding to their targets. CircRNAs also serve a key function in controlling the transcription and alternative splicing of the genes from which they are generated.

RNA Structures

The passage of genetic information from DNA to protein via an RNA intermediary is described by the basic dogma of molecular biology. For many years, RNA was thought to be nothing more than a messenger that passed information between DNA and proteins. The many vital roles of RNA in practically every biological process have been highlighted by recent advancements in next-generation sequencing technologies, bioinformatics, and non-coding RNA biology. A number of notable advances in examining RNA structures have added to our understanding of RNA biology.

Researchers now know that cells contain a number of RNA forms, including mRNA, tRNA, and rRNA, each of which plays a particular role in various tasks and activities. mRNA is a template for the production of one or more proteins. It is essentially a replica of a portion of DNA. tRNA binds to both mRNA and amino acids (protein building blocks) and, based on the nucleotide sequence of the mRNA, delivers the right amino acids into the developing polypeptide chain during protein production. Translation is the method by which proteins are created. Ribosomes, which are cellular organelles, are where translation takes place composed of protein and rRNA (Gunasekaran et al., 2014).

RNA molecules come in a variety of shapes and sizes, but they all have the same basic structure. Each type of RNA is a polymeric molecule created by stringing together individual ribonucleotides, with the 5’-phosphate group of one nucleotide always being added to the 3’-hydroxyl group of the preceding nucleotide. Each strand of RNA, like DNA, has the same basic structure: nitrogenous bases covalently bonded to a sugar-phosphate backbone. RNA, on the other hand, is usually a single-stranded molecule, unlike DNA. In addition, RNA’s sugar is ribose rather than deoxyribose (ribose has one additional hydroxyl group on the second carbon), which explains the molecule’s name (Figure 51).

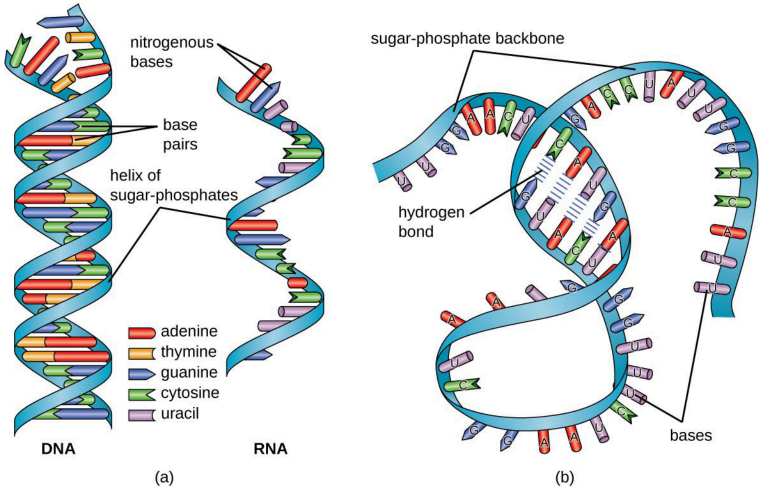


Figure 51. Structure and function of RNA.

Source: https://courses.lumenlearning.com/microbiology/chapter/structure-and-function-of-rna/.

Adenine, cytosine, uracil, and guanine are the four nitrogenous bases found in RNA. Uracil is a pyrimidine with a similar structure to thymine, another pyrimidine found in DNA. Uracil, like thymine, can base-pair with adenine.

RNA is a single-stranded molecule, but researchers quickly realized that it can create double-stranded structures that are crucial to its function. Single strands of RNA can "hybridize," bonding together to form a double-stranded molecule, according to Alexander Rich, an X-ray crystallographer and member of the RNA Tie Club, and David Davies, both National Institutes of Health.

The discovery in 1960 that an RNA molecule and a DNA molecule could form a hybrid double helix was the first experimental demonstration of a mechanism to transfer information from DNA to RNA.

Single-stranded RNA can also form a variety of secondary structures, such as hairpin loops, which are stabilized by intramolecular hydrogen bonds between complementary bases. Many RNA functions, such as the ability of tRNA to bind to the correct sequence of mRNA during translation, rely on such base-pairing. The structure of tRNA was first discovered by Robert Holley, a scientist at Cornell University.

Gene expression—the process of encoding the instructions stored in the sequence of DNA nucleotides in either RNA or protein molecules that carry out the cell's activities—involves several types of RNA. In this process, mRNA plays a crucial role. mRNA is mostly made up of coding sequences, which means it conveys the genetic information for a protein's amino acid sequence to the ribosome, where it is created. Noncoding, or untranslated, regions in each mRNA molecule may also provide instructions for how the mRNA is handled by the cell (Safari and Zarnegar, 2014).

S

Scanning Probe Lithography (SPL)

Scanning probe lithography (SPL) is a group of nanolithographic techniques that use scanning probes to design material at the nanoscale. It is a direct-write, mask-free method that avoids the diffraction limit and allows for resolutions of less than 10 nm. It is a type of alternative lithographic technology that is commonly utilized in academic and research settings. After the first patterning tests with scanning probe microscopes (SPM) in the late 1980s, the term SPL was coined.

SPM experiments can be used to control the design, positioning, and size of nanostructures for surface measurements, allowing for nanoscale patterning. Organic thin films with diameters in the tens of nanometers can be used to write nanopatterns. The chemistry of nanopatterns can be defined using scanning probe-based nanolithography (NL) by selecting molecular lengths and end groups of the molecules used for patterning (Ravichandran, 2010).

For writing nanopatterns, both the tip and the sample are submerged in clean solvent for nanoshaving. To write, the force applied to the AFM probe (0.5–30 nN) is raised to sweep molecules away from the surface. Exposed areas of gold substrate are uncovered by the sweeping action of the tip. The motion and force applied to the tip can be programmed to make designs along the trajectory of the scanning probe (Figure 52).

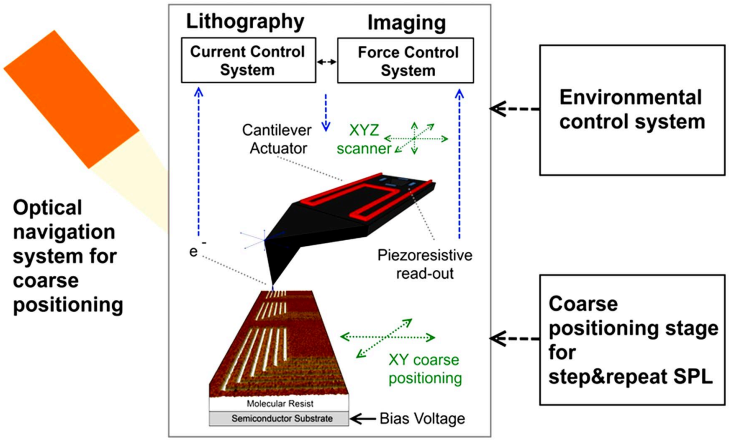


Figure 52. Schematic set-up of the scanning probe lithography system.

Source: https://www.researchgate.net/publication/264942439_Electric_field_scanning_probe_lithography_on_molecular_glass_resists_using_self-actuating_self-sensing_cantilever/figures?lo=1.

Both the tip and the sample are submerged in dilute solutions containing the ink molecules chosen for writing during nanografting. To identify a flat area for nanofabrication, the surface is first described under low force (less than 1 nN) (left). Without changing the surface, the sample can be described using low force. The force applied to the AFM probe is increased to enable writing (0.5–30 nN). The tip is pushed through the matrix monolayer with great force to shave away specified portions, and ink molecules from the solution quickly assemble on the surface following the AFM tip's scanning track (center). The same probe can then be used for imaging the SAM nanopatterns by returning to a low force setpoint.

SPL encompasses a number of techniques for patterning materials at the nanoscale level. The employment of a scanning sharp probe to make local alterations on a surface is common to all these methods. Two primary variables contribute to the diversity of SPL techniques:

- The wide range of processes that could be influenced by placing a sharp probe in or near a nanoscale region on a sample surface. Mechanical, thermal, electrostatic, and chemical interactions, as well as various combinations of these, are all involved in SPL processes (Presting and König, 2003).

- The various methods for controlling the position of the scanning probe relative to the underneath surface, such as quantum tunneling between the probe and a conductive surface in the STM or controlling the force between the probe and the surface in the standard atomic force microscope (AFM). In fact, an AFM is used in the majority of contemporary SPL procedures. In the early tests, the potential and range of approaches available to scanning probe microscopy (SPM) to locally change surfaces were already apparent.

In the early tests, the potential and range of approaches available to scanning probe microscopy (SPM) to locally change surfaces were already apparent. However, despite their atomic-scale manipulation capabilities, several of those techniques have proven unsuitable for large-scale patterning or device applications.

Self-Assembly

Self-assembly is a process in which a disordered system of pre-existing components, without external direction, produces a structured structure or pattern as a result of specific, local interactions among the parts. The process is known as molecular self-assembly when the constitutive components are molecules.

AFM imaging of 2-amino terephthalic acid molecule self-assembly on -oriented calcite. Static and dynamic self-assembly are two different types of self-assembly. The ordered state arises in static self-assembly as a system approaches equilibrium, lowering its free energy.

However, patterns of pre-existing components arranged by specific local interactions are not typically referred to as “self-assembled” by scientists in the related disciplines of dynamic self-assembly. Although the phrases “self-organized” and “self-contained” are frequently used interchangeably, “self-contained” is a better description of these structures.

Self-assembly is described as the spontaneous and reversible arrangement of molecular units into ordered structures through non-covalent interactions in the classic chemistry sense. This definition argues that the first attribute of a self-assembled system is the spontaneity of the self-assembly process: the interactions that lead to the production of the self-assembled system (Kaur et al., 2014).

Although self-assembly is most commonly seen between weakly interacting species, it can also be found in highly coupled covalent systems. The self-assembly of polyoxometalates provides an example of this. Evidence suggests that such molecules assemble via a dense-phase mechanism in which tiny oxometalate ions combine non-covalently in solution before becoming covalently bound by a condensation reaction. The inclusion of templating agents to control the generated species can facilitate this process. Highly structured covalent molecules can be created in a specific way in this approach.

A self-assembled nanostructure is an item formed by the ordering and aggregation of individual nano-scale particles in accordance with some physical principle.

Entropy maximization is a particularly counter-intuitive example of a physical principle that can promote self-assembly. Though entropy is commonly associated with disorder, it can drive nano-scale materials to self-assemble into desired shapes in a controlled manner given the right conditions.

Field-directed assembly is another major type of self-assembly. The phenomena of electrostatic trapping are one example of this. An electric field is applied between two metallic nano-electrodes in this scenario.

The applied electric field polarizes the particles present in the surroundings. The particles are drawn to the gap between the electrodes due to dipole interaction with the electric field gradient. There have also been reports of generalizations of this type of method employing different forms of fields, such as magnetic fields, capillary interactions for particles trapped at surfaces, and elastic interactions for particles suspended in liquid crystals.

People use self-assembly methods to materials synthesis to overcome the difficulty of having to create materials one building block at a time, regardless of the process driving self-assembly. Because the length of time necessary to place building blocks into a goal structure is too difficult for structures of macroscopic size, avoiding one-at-a-time techniques is critical (Kung and Kung, 2004).

Once macroscopic materials can self-assemble, they can be used in a variety of applications. Nano-structures, such as nano-vacuum gaps, are employed for energy storage and nuclear energy conversion, for example. Large surface area electrodes in batteries and organic photovoltaic cells, as well as microfluidic sensors and filters, are also good prospects for self-assembled tunable materials.

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Scanning Tunneling Microscope (STM)

STMs (scanning tunneling microscopes) are microscopes that are used to image surfaces at the atomic level. In 1986, its inventors, Gerd Binnig and Heinrich Rohrer, then at IBM Zürich, were awarded the Nobel Prize in Physics for their work in 1981. STM detects surface characteristics with a 0.01 nm (10 pm) depth resolution by utilizing a very sharp conducting tip that can identify features smaller than 0.1 nm. Individual atoms may now be seen and modified on a regular basis. The majority of microscopes are designed for use in ultra-high vacuum at temperatures near zero kelvin, although there are several that can be used in air, water, and other conditions, as well as at temperatures exceeding 1,000°C.

Quantum tunneling is the foundation of STM. A bias voltage provided between the tip and the surface to be studied permits electrons to tunnel through the vacuum separating them when the tip is brought very close to the surface to be examined. The resulting tunneling current is a function of the sample's local density of states (LDOS), applied voltage, and tip position.

The current is monitored while the tip scans across the surface, and the data is frequently shown as a picture (Figure 53).

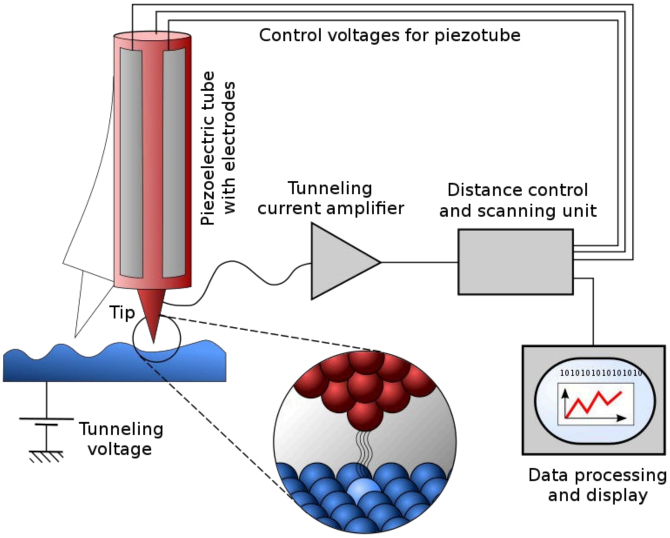

Control voltages for piezotube
Piezoelectric tube with electrodes
Tunneling current amplifier
Distance control and scanning unit
Tip
Tunneling voltage
101010101010101010
Data processing and display

Figure 53. Schematic view of an STM.

Source: https://en.wikipedia.org/wiki/Scanning_tunneling_microscope#/media/File:Scanning_Tunneling_Microscope_schematic.svg.

Scanning tunneling spectroscopy is a modification of the technique that involves holding the tip in a constant location above the surface while altering the bias voltage and monitoring the resulting change in current. The local density of electronic states can be recreated using this technique. To deduce the properties and interactions of electrons in the examined material, this is sometimes done in high magnetic fields and in the presence of contaminants.

Scanning tunneling microscopy is a difficult method to master because it necessitates exceptionally clean and stable surfaces, sharp tips, good vibration isolation, and complex electronics. Despite this, many enthusiasts construct their own microscopes.

Image artifacts can develop if the tip has more than one apex at the end; the most common case is double-tip imaging, in which both apices contribute equally to tunneling. While there are various methods for producing sharp, useable tips, the ultimate test of tip quality can only be performed when the tip is tunneling in a vacuum. The tips can be conditioned by providing high voltages to them when they are already in the tunneling region, or by forcing them to pick up an atom or a molecule off the surface every now and then (Porter et al., 2008).

The scanner in most recent designs is a radially polarized piezoelectric hollow tube with metallized surfaces. The outer surface is separated into four long quadrants that act as x and y motion electrodes, with two polarity deflection voltages applied on opposite sides. A lead zirconate titanate ceramic tube with a piezo constant of about 5 nanometers per volt is used. The tip is positioned in the tube's center. The movement is calibrated, and voltages required for independent x, y, and z motion are applied according to calibration tables due to some crosstalk between the electrodes and intrinsic nonlinearities.

Because the tunneling current is extremely sensitive to electrode separation, sufficient vibration isolation or a stiff STM body is required to achieve meaningful results.

Magnetic levitation was used in the initial STM by Binnig and Rohrer to keep the STM free of vibrations; presently mechanical spring or gas spring systems are commonly used. Additionally, eddy current-based vibration dampening techniques are sometimes used. Microscopes used in scanning tunneling spectroscopy require high stability and are built-in anechoic chambers—dedicated concrete rooms with acoustic and electromagnetic isolation that are floated on vibration isolation devices inside the laboratory.

The tip position with relation to the sample, the scanning of the sample, and the data acquisition are all computer-controlled. Image processing and quantitative measurements are done with dedicated software for scanning probe microscopies.

Scan tunneling microscopes can record pictures at high frame rates in some cases. Such images can be used to create videos that illustrate surface diffusion or follow adsorption and reactions. Frame rates of 80 Hz have been obtained in video-rate microscopes with fully operational feedback that adjusts the tip height.

Single-Wall Carbon Nanotubes (SWCNTs)

Carbon nanotubes (CNTs) are carbon tubes that have a diameter measured in nanometers. SWCNTs with dimensions in the nanometer range are commonly referred to as CNTs. CNTs with a single wall are an allotrope of carbon that sits halfway between fullerene cages and flat graphene.

SWCNTs can be idealized as cuttings from a two-dimensional hexagonal lattice of carbon atoms rolled up along one of the hexagonal lattice's Bravais lattice vectors to produce a hollow cylinder, albeit they are not made this way (Figure 54).

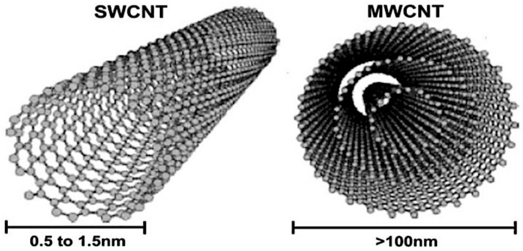


Figure 54. Single-walled carbon nanotube (SWCNT) and multi-walled carbon nanotube (MWCNT).

Source: https://www.researchgate.net/publication/319966218_Carbon_nanotube_buckypaper_reinforced_polymer_composites_A_review/figures?lo=1&utm_source=google&utm_medium=organic.

Periodic boundary conditions are imposed along the length of the roll-up vector in this fabrication, resulting in a helical lattice of flawlessly connected carbon atoms on the cylinder surface.

CNTs are also known as multi-wall carbon nanotubes (MWCNTs), which are made up of nested SWCNTs that are weakly bonded together in a tree ring-like structure by van der Waals interactions. These tubes resemble Oberlin, Endo, and Koyama's long straight and parallel carbon layers cylindrically stacked around a hollow tube, if not identical. Double- and triple-wall carbon nanotubes are also referred to as multi-wall carbon nanotubes (Patil et al., 2008).

Smart Materials and Products

The usage of nano-scale particles is relatively new, and it is still unknown what effect they will have on human health and the environment in the long run. Thermochromic pigments, shape memory polymers, form memory alloys, and hydrogels are examples of smart materials.

Smart materials are those that have qualities that can change reversibly, that is, they can change readily but then change back again in response to changes in their environment. Here are a few illustrations.

At specific temperatures, thermochromic pigments change color. Color-changing novelty mugs, color-changing spoons, battery power indicators, and forehead thermometers are just a few examples.

When exposed to light, photochromic pigments change color. This is typically found in photochromic lenses for glasses, which darken when exposed to ultraviolet (UV) light. This implies that on bright days, these glasses function as sunglasses, but when the lenses are no longer in direct sunlight, they swiftly transform into regular glasses.

When heated, a shape memory polymer may be twisted out of its original shape and then returned to its original shape. Sports equipment, like helmets and gum shields, or car bumpers, which may be heated to return to their former shape after a slight impact, are examples of possible applications. In addition, medical stitches can self-tighten as a wound heals (Pathakoti et al., 2018).

Form memory alloys, like shape memory polymers, are metal combinations that return to their original shape when heated. This form of smart material might be employed in athletic goods and automotive bodies, as well as medical applications like surgical plates for mending bone fractures. Because the alloy is warmed by the body, it exerts more tension than standard plates, allowing for speedier recovery. Nitinol, for example, is a nickel-titanium shape memory alloy.

In water, hydrogels can absorb 1,000 times their own volume. When the surrounding area is dry, the water can be discharged once it has been absorbed. Temperature and pH changes can also cause the hydrogel to release water.

Scaffold Scanning Probe Microscopy (SPM)

Recognition of Scanning Probes Microscopy is a new scanning probe capability that our lab is developing to dependably return to and directly interact with a specific nanoscale feature of interest without the use of a zoom box, which has problems with thermal drift and local origin. It uses a combination of SPM piezoelectric implementation, online image processing, and dynamically adaptive learning algorithms to create a recognition-driven and learning approach. A scan plan with segmentation and a recognized pattern is utilized to guide the tip in a recognition-driven return to a specific place.

The development of Scanning Probe Recognition Microscopy for nanobiological research is a specific application focus of our organization. Scanning Probe Recognition Microscopy was utilized to investigate the surface and elastic characteristics of individual tubules within a tissue scaffolding matrix in this study. Actin polymerization and, as a result, cell pseudopodia extension and contraction are influenced by elastic characteristics.

Scanning probe recognition microscopy is a novel type of scanning probe microscopy that allows for selective scanning of specific nanofibers within a tissue scaffold. By fine-scanning an identical region of interest repeatedly, statistically significant data for several attributes can be gathered. The surface roughness and elasticity of a variety of tissue scaffolds were investigated using scanning probe recognition microscopy. For data accuracy along curved nanofiber surfaces, deconvolution, and statistical algorithms were devised and used. Nanofiber features were also independently analyzed using transmission electron microscopy, with results that supported the scanning probe recognition microscopy-based analysis (Figure 55).

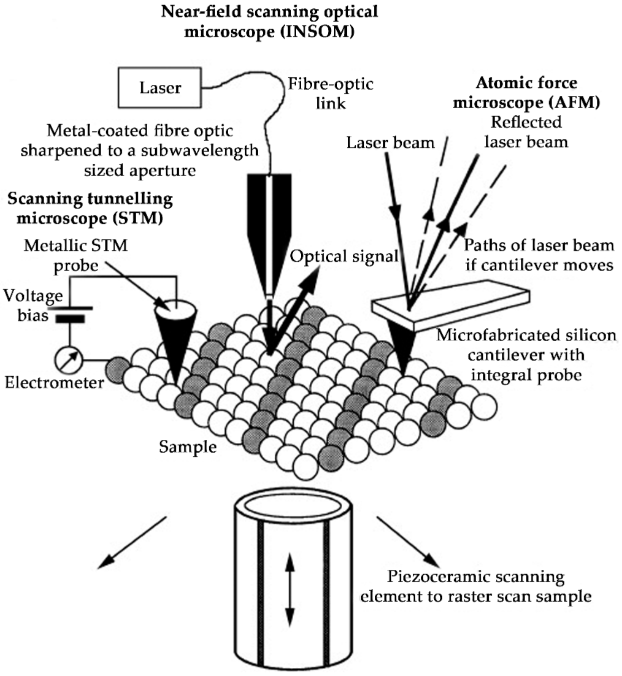

Near-field scanning optical microscope (INSOM)
Laser
Fibre-optic link
Metal-coated fibre optic sharpened to a subwavelength sized aperture
Atomic force microscope (AFM)
Reflected laser beam
Laser beam
Scanning tunnelling microscope (STM)
Metallic STM probe
Optical signal
Paths of laser beam if cantilever moves
Voltage bias
Microfabricated silicon cantilever with integral probe
Electrometer
Sample
Piezoceramic scanning element to raster scan sample

Figure 55. The key components of a scanning tunneling microscope (STM), a near-field scanning optical microscope (NSOM) and an atomic force microscope (AFM). In an STM, a sharp metallic probe is brought into close proximity with a conducting sample. A small bias voltage between probe and sample causes a tunneling current to flow. This current is recorded as the sample is

scanned beneath the probe. In NSOM, the sample is placed in the near-field region of a subwavelength-sized light source (Nikalje, 2015). The transmitted or reflected optical signal is used to form an image of the scanning sample. AFM microscopy relies upon the effect of repulsive and attractive forces between the probe and sample to bend a supporting cantilever. The bending of the cantilever, and hence the force, is extracted by monitoring the path of a laser beam reflected from the back of the cantilever.

Source: https://www.sciencedirect.com/topics/nursing-and-health-professions/scanning-probe-microscope.

Second-Harmonic Generation (SHG)

Second-harmonic generation (SHG, also known as frequency doubling) is a nonlinear optical process in which two photons of the same frequency interact with a nonlinear material, "combine," and generate a new photon with twice the energy of the initial photons (equivalently, twice the frequency and half the wavelength), preserving the excitation's coherence. It is a type of sum-frequency generation (two photons) and, more broadly, harmonic generation. The tendency of a medium to cause SHG is measured by its second-order nonlinear susceptibility. In media with inversion symmetry, second-harmonic production, like other even-order nonlinear optical processes, is prohibited. (In the leading electric dipole contribution).

Second-harmonic generation will occur in centrosymmetric systems due to factors such as the Bloch–Siegert shift (oscillation), which occurs when two-level systems are pushed at Rabi frequencies comparable to their transition frequencies. Furthermore, the SHG is not conceivable in non-centrosymmetric crystals belonging to crystallographic point group 432, and per Kleinman's criteria, SHG in the 422- and 622-point groups should vanish, albeit there are some outliers.

Almost all the light energy can be transferred to the second harmonic frequency in some instances. In these circumstances, powerful pulsed laser beams flow through massive crystals, and phase matching is achieved through meticulous alignment. Only a small fraction of the light energy is transformed to the second harmonic in other circumstances, such as second-harmonic imaging microscopy, but this light can still be detected using optical filters. The second harmonic, also known as frequency doubling, is a radio communication mechanism that was invented in the early 20th century and has been utilized with frequencies in the megahertz range. It is a type of frequency multiplication that is a little different.

Scientists at the University of Michigan, Ann Arbor, were the first to demonstrate SHG in 1961. The invention of the laser, which produced the requisite high intensity coherent light, made the demonstration possible. A ruby laser with a wavelength of 694 nm was focused into a quartz sample. They used a spectrometer to analyze the output light and recorded the spectrum on photographic paper, which revealed that light at 347 nm was produced. When it was published in the journal Physical Review Letters, the copy editor mistaken the dim spot on the photographic paper (at 347 nm) for a speck of dirt and had it erased (Klimeck et al., 2008).

N. Bloembergen and P. S. Pershan first outlined the formulation of SHG in 1962 at Harvard. Several rules for the interaction of light in nonlinear mediums were revealed in their detailed evaluation of Maxwell's equations at the planar interface between a linear and nonlinear medium.

The laser industry uses SHG to create green 532 nm lasers from a 1,064 nm source. A bulk KDP crystal receives the 1,064 nm light. In high-quality diode lasers, the output side of the crystal is covered with an infrared filter to prevent infrared light with wavelengths of 1,064 nm or 808 nm from entering the beam. Both wavelengths are invisible and do not cause the eye's defensive "blink-reflex," making them a particular hazard to humans' eyes. Furthermore, certain laser safety glasses designed for argon or other green lasers may filter out the green component while transmitting the infrared, giving the illusion of safety.

Nonetheless, several "green laser pointer" devices have appeared on the market, frequently without notice, omitting the costly infrared filter. With autocorrelators, SHG is also utilized to measure ultra-short pulse width.

Self-Assembled Monolayers (SAM)

During the deposition process, a self-assembled monolayer (SAM) is a one-molecule thick layer of material that adheres to a surface in an orderly manner as a result of physical or chemical processes. Silanes can be deposited as SAMs in a solution or vapor phase. Chlorosilanes and alkoxysilanes are the most often used silanes. A chemical (oxane or Si-O-M) bond forms with the surface after deposition, resulting in a permanent change of the substrate (Figure 56).

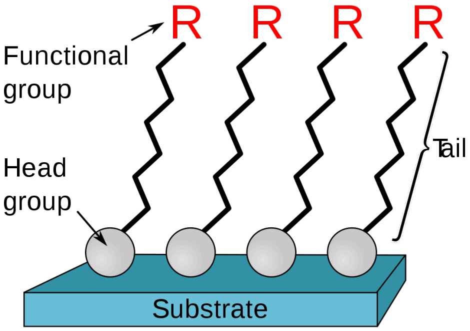


Figure 56. Representation of a SAM structure.

Source: https://en.wikipedia.org/wiki/Self-assembled_monolayer.

Simple hydrocarbon, fluoroalkyl, and end-group substituted silanes are common long-chain alkyl silanes employed in the synthesis of SAMs. By creating a single oxane bond with the substrate, silanes with one hydrolysable group maintain interphase structure following deposition. After deposition, silanes containing three hydrolysable groups create siloxane (silsesquioxane) polymers, which link to each other and to the substrate. Minimizing water condensation on the substrate can reduce random aggregation and interaction among the silanes while also increasing substrate adhesion. The density (or frequency) of a material's surface hydroxyl groups (M-OH) determines the formation of well-ordered oxane linkages, which differs between different materials.

Organic SAM are molecular assemblies that form spontaneously on surfaces through adsorption and are arranged into more or less massive ordered domains. In other circumstances, the monolayer molecules do not have a significant interaction with the substrate. For example, two-dimensional supramolecular networks of perylene tetracarboxylic dianhydride (PTCDA) on gold or porphyrins on highly orientated pyrolytic graphite are examples of this (HOPG). In other circumstances, the molecules have a head group that has a great affinity for the substrate and acts as an anchor for the molecule (Lakhal and Wood, 2011).

SAMs are formed by the chemisorption of "head groups" from the vapor or liquid phase onto a substrate, followed by the gradual organization of "tail groups." At low molecular density on the surface, adsorbate molecules form either a disordered mass of molecules or an ordered two-dimensional "lying down phase," and at higher molecular density on the surface, they begin to form three-dimensional crystalline or semicrystalline structures on the substrate surface over a period of minutes to hours. The "head groups" assemble on the substrate together, while the "tail groups" assemble far away from it.

Adsorbate molecules adsorb quickly because they lower the substrate's surface free energy and are stable due to the "head group's" high chemisorption. These bonds produce monolayers that are more stable than Langmuir–Blodgett films' physisorbed bonds. A FDTS molecule's Trichlorosilane-based "head group" combines with a hydroxyl group on a substrate to produce a very stable covalent bond [R-Si-O-substrate] with an energy of 452 kJ/mol. The thermal stability of thiol-metal bonds is on the order of 100 kJ/mol, which makes them relatively stable in a wide range of temperatures, solvents, and potentials. Due of van der Waals interactions, the monolayer packs tightly, lowering its own free energy. If lateral interactions are ignored, the Langmuir adsorption isotherm can be used to characterize the adsorption. If they cannot be ignored, the Frumkin isotherm is a better fit for the adsorption.

Organic electronic devices such as organic light-emitting diodes (OLEDs), organic photovoltaics (OPVs), organic thin-film transistors (OTFTs), and nonvolatile memories now rely on SAMs as critical interlayers and electronically active layers (NVMs). The utilization of self-assembling functionalized silanes is still advantageous due to three primary benefits over traditional thin-film deposition methods.

- Surface selectivity determines molecular self-assembly, which is determined by the contact between the silane coupling agent's functional anchor group (chloro or alkoxy) and the target surface.
- The ensuing layers' film thickness is controlled on an angstrom scale, resulting in a single molecular layer from the self-terminating film creation.
- Gelest's silanes have a wide range of chemical structures, allowing for a variety of SAM capabilities for devices, including electrical insulation, charge storage, and charge transport. The SAM technique can be pushed even further by using multiple functionalized silanes at the same time to make mixed SAMs with mixed characteristics.

Simulation

Simulation is a study or teaching approach used in industry, science, and education to replicate real-world events and processes under controlled settings. Creating a simulation is frequently a difficult mathematical task. Initially, a collection of rules, relationships, and operating processes, as well as other factors, are described. As these events interact, new scenarios and even laws emerge, which continue to evolve as the simulation progresses. From simple paper-and-pencil and board-game reproductions of scenarios to large computer-aided interactive systems, simulation tools come in all shapes and sizes.

Researchers can use simulation techniques to execute unique "dry lab" experiments or demonstrations without having to use rare materials or expensive equipment. In the automotive sector, proposed automobile designs are subjected to computer simulations of wind tunnel tests, saving hundreds of hours formerly spent developing and testing prototypes. Another cost-cutting characteristic of simulation technology is time compression. In real-time, events that typically take hours to eons can be replicated in a matter of minutes. Medical researchers, for example, must frequently isolate organs and artificially keep them alive, develop cultures, inject drugs, and wait for results (Lieber, 2003).

When the typical operations of a certain organ can be adequately reproduced, researchers can monitor the effects of a wide range of events on that functioning in a matter of minutes. Similarly, astronomers can illustrate events that take millions of years to complete, such as the collision of two galaxies, using computer simulations of galactic movements to evaluate the veracity of theoretical explanations.

Simulation as a teaching method helps pupils to deal realistically with important issues while avoiding catastrophic repercussions if they make poor decisions. The technology has been particularly beneficial in medical education, such as at the University of Alberta Medical School, where a computer models patients in critical condition who would die if they are not treated properly. In order to keep the patient alive, aspiring doctors are expected to make quick diagnoses and suggest therapies. By using advanced simulation systems like the Link trainer, aircraft-pilot students are also exposed to genuine emergency circumstances.

Students can use simulations to learn about the intricate interplay of physical and social environment elements. Students at Dartmouth College, for example, play a simulation game in which they try to develop a healthy rice crop while avoiding bugs, fire, and flooding. The Northwestern University Graduate School of Management has configured its computer to mimic a micro-model of the American economy. Students offer answers to economic problems using portable terminals and television displays, then compare their predictions to data from the model.

Simulating the operation of a real-world process or system over time is called simulation. Models are required for simulations; the model reflects the key characteristics or behaviors of the chosen system or process, while the simulation shows the model's progression across time. Computers are frequently used to run simulations). (Lü et al., 2009).

Simulation is utilized in a variety of applications, including technology simulation for performance tuning and optimization, safety engineering, testing, training, education, and video games. In economics, simulation is also utilized with scientific modeling of natural or human systems to obtain insight into how they work.

Simulation can be used to demonstrate the real-world consequences of certain conditions and actions. When the real system cannot be utilized because it is not accessible, or it is unsafe or unacceptable to use, or it is being created but not yet built, or it simply does not exist, simulation is employed.

The acquisition of valid sources of information about the relevant selection of key characteristics and behaviors used to build the model, the use of simplifying approximations and assumptions within the model, and the fidelity and validity of the simulation outcomes are all important issues in modeling and simulation.

Procedures and protocols for model verification and validation are a topic of academic study, refinement, research, and development in simulations technology or practice, notably in computer simulation work.

Single-Molecule Studies

A single-molecule experiment is one in which the properties of individual molecules are investigated. Measurements on an ensemble or bulk collection of molecules, in which individual molecule behavior cannot be differentiated and only average features can be measured, are in contrast to single-molecule research. Because many measurement techniques in biology, chemistry, and physics are not sensitive enough to see single molecules, single-molecule fluorescence techniques (which have been around since the 1990s for probing various processes at the molecular level) sparked a lot of interest because they revealed a lot of previously unknown information about the processes were not accessible in the past. Indeed, since the 1990s, many techniques for probing individual molecules have been developed (Manjunatha et al., 2016).

Patch-clamp experiments from the 1970s were the first single-molecule experiments, although they were only used to research ion channels. Single-molecule approaches are now being used to study the movement of myosin on actin filaments in muscle tissue, as well as the spectroscopic features of particular local environments in solids. The conformations of biological polymers have been measured using atomic force microscopy (AFM). Single molecules (or pairs of interacting molecules) can be mechanically stretched and their elastic response recorded in real-time using force spectroscopy.

The field of single-molecule research has grown at a dizzying speed over the last two decades, pushed by technological advancements and the promise of transformative skills to reveal previously buried information. In traditional ensemble experiments, a huge number of molecules are examined at the same time, and the results are essentially averaged-out attributes. Single-molecule experiments, on the other hand, allow unprecedented access to molecular data, appearing limited only by the practitioner's imagination and resourcefulness.

The scientific community can now ask and answer previously 'unanswerable' problems in the physical, chemical, and biological sciences thanks to these strong capabilities. These breakthroughs have a wide range of applications, including quantum optics, polymer, and photophysics, chemical bonding theory, and the folding, assembly, dynamics, and function of proteins and other cellular machineries in vitro and in vivo.

The field of single-molecule science can be separated into two broad categories: improving and developing single-molecule and supporting procedures, and applying these approaches to relevant scientific problems. Single-molecule research has encouraged much outstanding collaboration over the past decade, spawning a rich array of really interdisciplinary research including aspects from biology, chemistry, and physics, owing to the various knowledge required to achieve important advances in the field.

When looking at data from individual molecules, one can generally build propagators and jumping time probability density functions of the first, second, and so on, however when looking at data from bulk studies, one can usually get the decay of a correlation function. One may derive a relatively clear image of how the system acts from the information included in these distinct functions (obtained from individual molecules), such as its kinetic scheme, its potential of activity, or its reduced dimensions shape (Marcato and Durán, 2008).

When monitoring the activity of an individual enzyme, one can create (many features of) the reaction pathway of that enzyme. Several writers have also addressed important features of the analysis of single-molecule data, such as fitting algorithms and tests for homogeneous populations. On the other hand, there are various challenges with single-molecule data analysis, including the need for a low-noise environment and insulated pipet tips, filtering some of the remaining undesired components (noise) discovered in recordings, and the time required for data analysis (pre-processing, unambiguous event detection, plotting data, etc.).

Single-Source Precursors

Carbon dioxide is used to build material particles from single-source precursors. It is possible that the carbon dioxide is supercritical. To produce material particles, single-source precursors can be exposed to supercritical fluids other than supercritical carbon dioxide. The techniques could be utilized to make nanoparticles. The procedures are utilized to make chalcopyrite materials in various embodiments. Devices containing such particles, such as semiconductor devices, may be created. To make semiconductor devices, single-source precursors are exposed to carbon dioxide to form semiconductor material particles, and electrical contact is established between the particles and an electrode.

Optics, electronics, biology, and chemistry have all been influenced by single-molecule techniques. The study of proteins and other complex biological machinery in the biological sciences was formerly limited to ensemble studies, which made direct observation of their dynamics practically impossible. Direct examination of the walking mechanisms was only possible once single-molecule fluorescence microscopy was employed to analyze kinesin-myosin couples in muscle tissue. However, because useful techniques for live cell imaging have yet to be fully achieved, this research has mostly been limited to in vitro studies.

However, the promise of single-molecule in vivo imaging comes with a huge possibility for directly observing biomolecules in their natural environments. These methods are frequently used in investigations involving low-copy proteins, which are still being found in large numbers. These methods have also been applied to chemistry research, such as the mapping of heterogeneous surfaces (Mei et al., 2011).

Metal oxides are one of the most diverse and widely used classes of solid materials, with a wide range of compositions, structures, and characteristics. Metal oxides are utilized in solar cells, photocatalysis, batteries, transistors, ferroelectric, and multiferroic materials, supercapacitors, superconductors, luminous materials, and gas sensors, among other things. Hetero-metals, either as stoichiometric components or as dopants, can improve the characteristics of metal oxides. This adds to the synthesis's complexity.

Sol-Gel Materials

The sol-gel process is a method for creating solid materials from tiny molecules in materials science. Metal oxides, particularly those of silicon (Si) and titanium (Ti), are made using this approach (Ti). The method entails converting monomers into a colloidal solution (sol), which serves as a precursor for forming an integrated network (or gel) of discrete particles or network polymers. Metal alkoxides are common precursors. A "sol" (a colloidal solution) is generated in this chemical technique, which then grows into a gel-like diphasic system having both a liquid phase and a solid phase with different morphologies from discrete particles to continuous polymer networks. In the case of the colloid, the volume fraction of particles (or particle density) may be so low that a significant amount of fluid may need to be removed initially for the gel-like properties to be recognized.

This can be achieved in a variety of ways. Allowing time for sedimentation and then pouring out the leftover liquid is the easiest way. Centrifugation can also be utilized to speed up the phase separation process.

Drying is required to remove the remaining liquid (solvent) phase, which is usually accompanied by substantial shrinkage and densification. The distribution of porosity in the gel ultimately determines the rate at which the solvent can be extracted. Changes imposed on the structural template during this phase of processing will definitely have a significant impact on the final component's microstructure.

Following that, a thermal treatment, or fire procedure, is frequently required to promote further polycondensation as well as improve mechanical characteristics and structural stability through final sintering, densification, and grain development. One of the major advantages of this procedure over more typical processing techniques is that densification can often be accomplished at a significantly lower temperature (Figure 57).

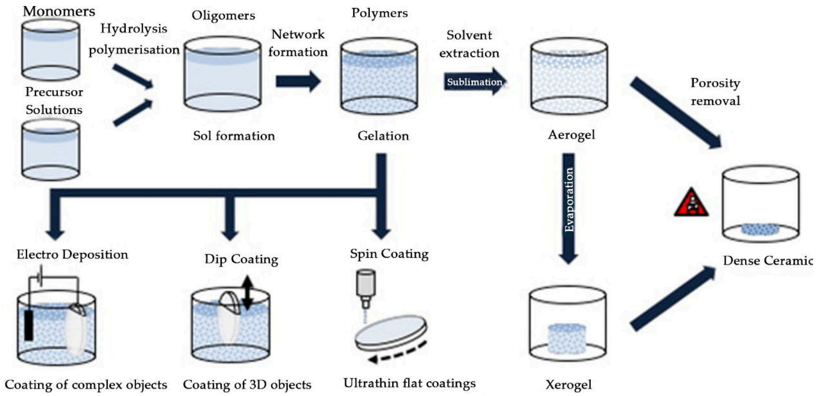


Figure 57. Sol-gel synthesis routes. Processes are defined as sol-gel by the transition of colloidal solution to an interconnected gel network (gelation). The further processing stages illustrated are non-redundant and may be combined depending on the specific needs of the application.

Source: https://www.sciencedirect.com/science/article/pii/S0079642516000025.

The precursor sol can be coated on a substrate to produce a film (e.g., by dip-coating or spin-coating), cast into an appropriate container with the necessary shape (e.g., to make monolithic ceramics, glasses, fibers, membranes, or aerogels), or utilized to make powders. (e.g., microspheres, nanospheres).

The sol-gel method is a low-cost, low-temperature method for finely controlling the chemical composition of a product. Small amounts of dopants, such as organic dyes and rare-earth elements, can be added to the sol and disseminated equally in the final product. It can be utilized as an investment casting material in ceramics processing and manufacturing, or as a method of generating very thin metal oxide coatings for various applications. Optics, electronics, energy, space, (bio)sensors, medicine (e.g., controlled medication release), reactive materials, and separation (e.g., chromatography) technology all use sol-gel produced materials (Mitter and Hussey, 2019).

The discovery that the hydrolysis of tetraethyl orthosilicate (TEOS) under acidic circumstances resulted in the creation of SiO_2 in the form of fibers and monoliths sparked interest in sol-gel processing in the mid-1800s. Sol-gel research became so prominent in the 1990s that more than 35,000 articles on the method were published globally.

The applications for sol gel-derived products are numerous. For example, scientists have used it to produce the world's lightest materials and also some of its toughest ceramics.

Thin films, which can be created on a piece of substrate by spin coating or dip coating, are one of the most common applications. These processes can be used to apply protective and decorative coatings as well as electro-optic components to glass, metal, and other surfaces. Cast into a mold, and then dried and heat-treated, dense ceramic or glass products with novel qualities that cannot be made any other way can be developed.

Both optical and refractory ceramic fibers, which are used for fiber optic sensors and thermal insulation, can be pulled with the viscosity of a sol regulated into a proper range. Thus, many ceramic materials, both glassy and crystalline, have found use in various forms from bulk solid-state components to high surface area forms such as thin films, coatings, and fibers.

Precipitation can produce ultra-fine and homogeneous ceramic powders. For dental and biomedical applications, nanoscale particle size powders of single and multiple component compositions can be created. Agrochemicals and herbicides made from composite powders have been patented. A sol-gel technique is used to make powder abrasives, which are employed in a range of finishing activities (Mousavi and Rezaei, 2011).

Another scientific application is to entrap biomolecules for sensing (biosensors) or catalytic reasons by physically or chemically preventing them from leaching out and, in the case of protein or chemically-linked small molecules, by sheltering them from the outside environment yet allowing small molecules to be monitored.

The sol-gel technique can be used to make macroscopic optical elements and active optical components, as well as large-area hot mirrors, cold mirrors, lenses, and beam splitters, all with ideal geometry. The size of the crystalline grains is mostly determined by the size of the crystalline particles present in the raw material during the synthesis or production of the object in the processing of high-performance ceramic nanoparticles with excellent optomechanical properties under adverse conditions. The sol-unique gel's features allow it to be used in a wide range of medical applications. A sol-gel processed alumina can be used as a carrier for the sustained delivery of drugs and as an established wound healer. A marked decrease in scar size was observed because of the wound healing composite including sol-gel processed alumina.

Solid-State Reactions

For the creation of polycrystalline solids from a mixture of solid starting materials, the solid-state reaction pathway is the most extensively employed approach. Solids do not react at room temperature over normal time scales, and must be heated to much higher temperatures, often 1,000 to 1,500°C, for the reaction to occur at a reasonable rate. Reaction circumstances, structural features of the reactants, surface area of the solids, their reactivity, and the thermodynamic free energy change associated with the reaction are all elements that influence the feasibility and rate of a solid-state reaction.

Solid-state organic reactions have also been studied for many years, and various principles have been created to help comprehend the chemistry involved in this subject. However, there is little evidence that this expertise has been transferred to the realm of organometallic chemistry (Figure 58).

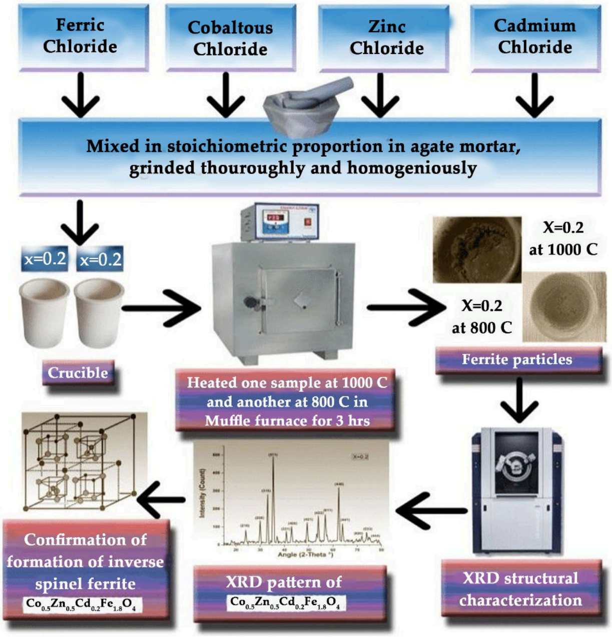

Ferric Chloride
Cobaltous Chloride
Zinc Chloride
Cadmium Chloride
Mixed in stoichiometric proportion in agate mortar, grinded thouroughly and homogeniously
x=0.2
x=0.2
Crucible
Heated one sample at 1000 C and another at 800 C in Muffle furnace for 3 hrs
X=0.2 at 1000 C
X=0.2 at 800 C
Ferrite particles
XRD structural characterization
Intensity (Count)
Angle (2-Theta °)
X=0.2
(311)
(440)
XRD pattern of $Co_{0.5}Zn_{0.5}Cd_{0.2}Fe_{1.8}O_4$
Confirmation of formation of inverse spinel ferrite $Co_{0.5}Zn_{0.5}Cd_{0.2}Fe_{1.8}O_4$

Figure 58. Schematic diagram of solid-state reaction method of Co0.5Zn0.5Cd0.2Fe1.8O4 ferrite for 800°C and 1,000°C sintering temperatures.

Source: https://www.researchgate.net/publication/324109011_Effect_of_Sintering_Temperature_on_Structural_Properties_of_Cd_doped_Co-Zn_Ferrite/figures?lo=1.

This scenario is due to a variety of factors. I Aristotle's famed philosophy, according to which "No reaction happens without a solvent." This concept had a significant impact on the evolution of synthetic chemistry, and numerous reactions were carried out in the presence of solvents even when there was no reason to do so; (ii) lack of reactant interaction; (iii) the delicate nature of the organometallic complexes, i.e., they easily decompose on heating and react with oxygen and moisture to give undesirable products and (iv) lack of techniques available to study reactions in a confined environment.

Although X-ray diffractometers were available in the early investigations on organometallic complexes, their use was time demanding, and they were mostly utilized for structural determination, with little emphasis on the study of solid-state processes. However, recent advances in diffractometer design, as well as the availability of equipment for thermal analysis (e.g., differential scanning calorimetry, thermal gravimetric analysis), solid-state NMR spectroscopy, optical microscopy (for visualizing the reaction), DRIFTS, and other related techniques, have made it possible to study reactions in the solid-state and under inert atmospheres in recent years (Morrow et al., 2007).

Solvent-free reactions are defined as reactions between or inside solid reactants that result in a solid product. Chemical reactivity between solids (and, in many cases, within solids) is difficult to characterize, according to literature. Reactions that took place in the melt were not considered true solid-state reactions. The same was true for reactions that happened as a result of crystal degradation before the reaction. Solid-state reactions are defined as any solvent-free processes that lead from a solid reactant to a solid product in this thesis. Because they can eventually generate a solid result, gas-solid reactions will also be considered solid-state reactions.

The difference between solid-state and solution reactions is that solid-state reactions take place within the crystal lattice's rigorous confining environment (reaction cavity concept). As a result, solid-state reactions are an extreme situation for examining the effect of intermolecular interactions on a reaction and their impact on the mechanism and direction of the reaction. The reactant crystal lattice's constrained environment might influence the kinetics of a reaction and, as a result, the nature of the products. Such reactions are known as topochemically regulated reactions, and they demonstrate Cohen and Schmidt's topochemical principle, according to which solid-state reactions occur with minimal requirement of energy and atomic or molecular motion requirements.

Substrate

A substrate is a molecule that an enzyme reacts with. The enzyme's active site, or the location where weak bonds between the two molecules can form, is loaded with a substrate. An enzyme-substrate complex is formed, and the enzyme's pressures on the substrate drive it to react and become the planned reaction's result. The conformational change, or shape change, in the enzyme is caused by the bonds that form between the substrate and the enzyme. The pressure applied to the substrate is caused by the ensuing shape change, which either forces molecules together or tears them apart.

At some point in our lives, almost every molecule in our bodies is a substrate molecule. Because most reactions require a significant amount of energy and time to complete, each reaction requires its own enzyme to assist it. An enzyme accomplishes this by reducing the amount of energy required for a reaction to occur between substrate molecules or within a single molecule. The substrate is now chemically altered and is referred to as the product after the reaction has occurred. Many of the compounds made by our bodies, on the other hand, are created through a series of smaller stages known as intermediates, each with its own enzyme. Until the end product is retrieved, the products of one reaction become the substrate for the next reaction. It is in this way that all the materials in our body take shape (Arora et al., 2014).

In the gut, nutrients gathered by an organism are digested. Enzymes detect different types of food as the substrate on which they function and try to break them up. These compounds are delivered to numerous cells throughout the body once they have been broken down. New enzymes act on these compounds, which are now referred to as substrates, to combine them into larger molecules and incorporate them into the body. A substance's status as a substrate is determined by which reaction it is destined for and which reaction it originated from. If a different enzyme can operate on a substrate after it has become a product, it can instantaneously become a substrate again. Because enzymes are specific and decrease reaction time, we can produce many chemicals that would be completely impossible without intermediate steps, and enzymes doing most of the work.

Lactase, the enzyme needed to act on lactose as a substrate, is produced by humans when they are babies to deal with the lactose in breastmilk. Once weaned from breastmilk, the substrate lactose is no longer present for the enzyme to work on. The lactose, besides being a substrate for lactase, also acts on your DNA.

Ground substance is an amorphous gel-like substance that contains all extracellular matrix (ECM) components except fibrous elements like collagen and elastin in the extracellular space. The formation, mobility, and proliferation of tissues, as well as their metabolism, are all aided by ground material. Cells also employ it for support, water storage, binding, and as a medium for intercellular communication (especially between blood cells and other types of cells). Collagen fibers are lubricated by a ground material.

The ground substance's composition varies based on the tissue. Water and big organic molecules like as glycosaminoglycans (GAGs), proteoglycans, and glycoproteins make up the majority of the ground substance. GAGs are polysaccharides that retain water and give a gel-like feel to the ground product. Hyaluronic acid, heparan sulfate, dermatan sulfate, and chondroitin sulfate are all GAGs present in ground material. GAGs are attached to proteins termed proteoglycans, with the exception of hyaluronic acid. Glycoproteins are proteins that bind ground substance components to one another and to cell surfaces.

Superconductor

When a substance cools below a "critical temperature," it becomes a superconductor, which conducts electricity without resistance. Electrons can readily pass through the substance at this temperature. Ordinary conductors, even very good ones, are not superconductors. Ordinary conductors gradually decrease resistance as they become cooler. Superconductors, on the other hand, lose their resistance all at once. A phase transition is something like this. Superconductivity is destroyed by high magnetic fields, and the normal conducting state is restored.

By electromagnetic induction, a magnet traveling near a conductor induces currents in the conductor. But a superconductor actually pushes out magnetic fields entirely by inducing surface currents. Instead of letting the magnetic field pass through, the superconductor acts like a magnet pointing the opposite way, which repels the real magnet. This is called the Meissner effect, and it can be demonstrated by levitating a superconductor over magnets or vice versa (Figure 59).

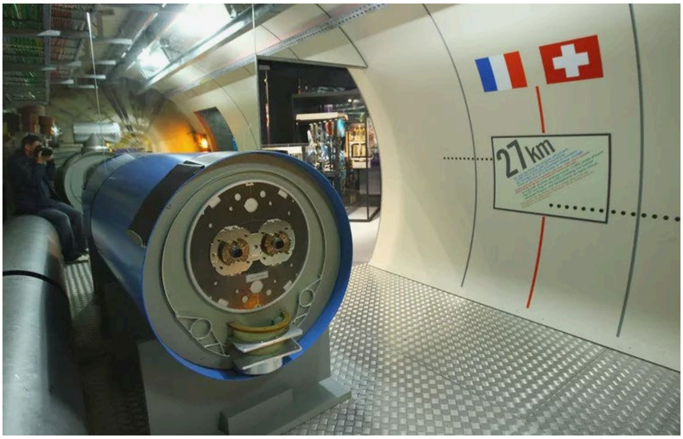


Figure 59. A model of the Large Hadron Collider (LHC) tunnel is seen in the CERN (European Organization for Nuclear Research) visitors' center.

Source: https://www.thoughtco.com/superconductor-2699012.

Superconductivity is explained by physicists by describing what happens when temperatures drop below a certain point. The thermal energy in a solid or liquid shakes the atoms, causing them to vibrate randomly, but when the temperature drops, this happens less. Electrons all have the same negative electric charge, thus they repel one another. Each electron behaves as though it were a free particle at greater temperatures. When electrons are in a solid or liquid, however, there is a very weak attraction between them. The attractive effect and absence of thermal energy allow pairs of electrons to hang together at relatively vast distances (several hundreds of nanometers apart) and low temperatures (near absolute zero).

A cooper pair is a quasiparticle that operates as if it were a new form of particle in and of itself, despite the fact that it is made up of two fundamental electrons. In the same nanometer-sized area, many overlapping cooper pairs can exist. Because paired electrons make up a boson, the motions of all cooper pairs within a single superconductor synchronize and they behave as if they were one. Small disruptions, such as electron scattering, are prohibited in this state, and it flows as one with no resistance. As a result, it is now a superconductor (Xia, 2008).

Some of the most powerful electromagnets are superconducting magnets. They are employed in MRI/NMR equipment, mass spectrometers, particle accelerator beam-steering magnets, and plasma confining magnets in some tokamaks. They can also be used for magnetic separation, such as in the pigment industry, where weakly magnetic particles are removed from a background of less or non-magnetic particles. They can also be employed in big wind turbines to overcome the limitations of high electrical currents, with a 3.6-megawatt superconducting windmill generator being successfully tested in Denmark.

Superconductors were utilized to make experimental digital computers utilizing cryotron switches in the 1950s and 1960s. Superconductors have lately been used in the development of digital circuits based on quick single flux quantum technology, as well as RF and microwave filters for mobile phone base stations.

Josephson junctions, the building blocks of SQUIDs (superconducting quantum interference devices), the most sensitive magnetometers known, are made of superconductors. Scanning SQUID microscopes and magnetoencephalography both use SQUIDs.

The SI volt is realized using a series of Josephson devices. A superconductor-insulator-superconductor Josephson junction can be employed as a photon detector or a mixer, depending on the mode of operation. In cryogenic micro-calorimeter photon detectors, the substantial resistance change at the transition from normal to superconducting state is employed to produce thermometers. Ultrasensitive bolometers constructed of superconducting materials exploit the same phenomenon (Abolmaali et al., 2013).

Other early markets are emerging, where the relative efficiency, size, and weight benefits of devices based on high-temperature superconductivity exceed the increased costs.

For example, in wind turbines, superconducting generators' lower weight and volume could result in cost reductions in building and tower expenses, offsetting the higher generator prices and lowering the total Levelized cost of power (LCOE).

High-performance smart grids, electric power transmission, transformers, power storage devices, electric motors (for vehicle propulsion, such as vactrains or maglev trains), magnetic levitation devices, fault current limiters, enhancing spintronic devices with superconducting materials, and superconducting magnetic refrigeration are among the promising future applications.

However, because superconductivity is sensitive to shifting magnetic fields, alternating current applications (such as transformers) will be more challenging to develop than direct current ones. Superconducting transmission lines are more efficient than regular power lines and take up a fraction of the space, which would not only improve environmental performance but also improve public acceptance of electric grid growth.

A type I superconductor is made up of fundamental conductive elements found in everything from electrical cables to computer microchips. At standard pressure, type I superconductors have Tcs ranging from 0.000325°K to 7.8°K. To attain the superconductive state, some type I superconductors require enormous quantities of pressure. To achieve superconductivity, sulfur must be subjected to a pressure of 9.3 million atmospheres (9.4 × 1,011 N/m^2) and a temperature of 17°K (Weiss et al., 2020).

Metallic compounds such as copper or lead make up a type II superconductor. When compared to type I superconductors, they enter a superconductive state at substantially greater temperatures. The source of this huge rise in temperature is yet unknown. To date, a compound ($HgBa_2Ca_2Cu_3O_8$) that belongs to the cuprate perovskites group of superconductors has achieved the highest Tc at standard pressure of 135°K or –138°C. This type of superconductor is classified as a ceramic because it has a ratio of two copper atoms to three oxygen atoms. A magnetic field can penetrate type II superconductors, but not type I superconductors.

Superhydrophobic

Surfaces that are ultrahydrophobic (or superhydrophobic) are exceedingly hydrophobic, meaning they are difficult to wet. A water droplet's contact angles with an ultrahydrophobic substance reach 150°. This is also known as the lotus effect, after the lotus plant's superhydrophobic leaves. When a droplet hit one of these surfaces, it bounces back like an elastic ball. Special superhydrophobic surfaces that encourage symmetry breaking, pancake bouncing, or water bowl bouncing can further minimize interactions between bouncing drops.

Cassie's law is used by many highly hydrophobic materials found in nature, and they are biphasic at the submicrometer level. Some plants have fine hairs that are hydrophobic, which are designed to use the solvent characteristics of water to attract and remove dirt from their photosynthetic surfaces. Many practical superhydrophobic surfaces have been developed as a result of the lotus effect.

Water striders are insects that live on the water's surface film, and their bodies are effectively unwettable due to specialized hair piles known as hydrofuge. Many of their body surfaces are covered with these specialized "hairpiles," which are made up of tiny hairs spaced so closely that there are more than 1,000 microhairs per mm, which creates a hydrophobic surface (West and Halas, 2000).

Other insects with hydrophobic hairs that prevent water from entering their respiratory system, such as aquatic insects that spend most of their lives submerged, have similar hydrofuge surfaces.

Because of their hydrophobic feather coating, some birds are excellent swimmers. Penguins are covered in a coating of air that they can release to accelerate while jumping out of the water and landing on higher ground. Swimming with an air coat decrease drag while also acting as a heat insulator.

Dettre and Johnson observed in 1964 that the superhydrophobic lotus effect was linked to rough hydrophobic surfaces, and they constructed a theoretical model based on studies with paraffin or TFE telomer-coated glass beads. In 1977, it was discovered that superhydrophobic micro-nanostructured surfaces have self-cleaning properties. Between 1986 and 1995, perfluoroalkyl, perfluoropolyether, and RF plasma generated superhydrophobic materials were created, electrowetted, and commercialized for biomedical uses. Since the mid-1990s, new technology and applications have emerged.

With the publication of a letter recently describing man-made superhydrophobic samples manufactured by enabling alkylketene dimer (AKD) to solidify into a nanostructured fractal surface, superhydrophobicity research has quickened. Particle deposition, sol-gel procedures, plasma treatments, vapor deposition, and casting techniques are only a few of the fabrication methods for superhydrophobic surfaces that have been published since then. Fundamental research and practical manufacturing are the main areas where research can have an impact right now. The applicability of the Wenzel and Cassie-Baxter models has recently become a source of debate (Figure 60).

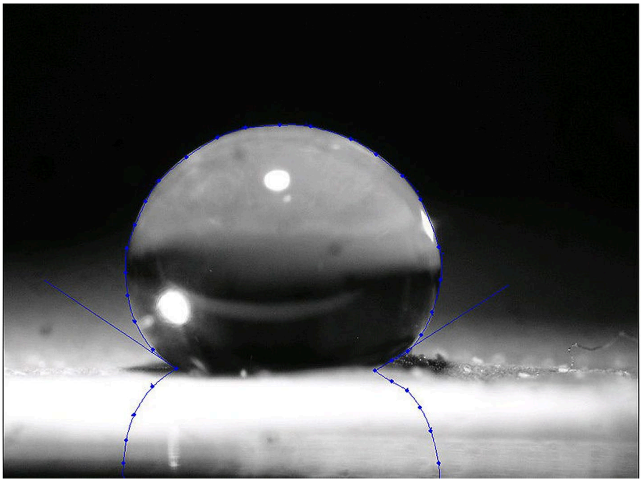


Figure 60. A drop on a lotus surface, with a contact angle of greater than 146°.

Source: https://en.wikipedia.org/wiki/Ultrahydrophobicity#/media/File:DropConnectionAngel.jpg.

A few attempts have been made to create a surface with variable wettability. A surface can be constructed with various tower widths and spacings to gradually raise the surface's free energy for the goal of spontaneous droplet mobility. The trend demonstrates that as the tower width grows, the free energy barrier grows larger and the contact angle decreases, lowering the material's hydrophobicity. The contact angle will grow when tower spacing is increased, but the free energy barrier will also increase. Droplets naturally gravitate toward locations with low hydrophobicity, hence the best surface for making a droplet spontaneously travel from one spot to the next would be a series of narrow width towers with large spacing to large width towers with small spacing (Thompson, 2011).

Specially developed fabrics are an example of easily changeable wettability. Contact angles were often permitted to rise by stretching a dip-coated commercial fabric. An increase in tower spacing is largely to blame. With higher strain, however, the tendency toward enhanced hydrophobicity does not continue. The Cassie-Baxter state eventually reaches an unstable condition and switches to the Wenzel state, which soaks the fabric.

Nanopin film is an example of a biomimetic superhydrophobic material used in nanotechnology. A vanadium pentoxide surface that may transition reversibly between superhydrophobicity and superhydrophilicity under the impact of UV radiation is shown in one study.

Recent active research on superhydrophobic materials could lead to practical uses in the future. The two-tiered property of a lotus leaf surface has been mimicked in several attempts to fabricate a superhydrophobic surface. This necessitates the use of micro-scale surfaces with nanoscale characteristics on top of them. A simple process has been published for coating cotton fabric with silica or titania particles using the sol-gel technology, which protects the cloth from UV rays and renders it superhydrophobic. Similarly, silica nanoparticles can be put on top of a carbon fabric that is already hydrophobic. The carbon fabric by itself is identified as inherently hydrophobic, but not distinguished as superhydrophobic since its contact angle is not higher than 150°.

It has also been suggested that superhydrophobic surfaces might reject ice or inhibit ice accumulation, resulting in the icephobicity phenomena. However, not all superhydrophobic surfaces are icephobic (Kung and Kung, 2004), and the technique is continuously being refined (Sozer and Kokini, 2009). As a result of undesirable inter-droplet freezing wave propagation initiated by the sample margins, frost formation across the entire surface is unavoidable. Furthermore, frost production causes greater frost adhesion, making the subsequent defrosting process extremely difficult. Interdroplet freezing wave propagation can be prevented by establishing a hierarchical surface whereas the ice/frost removal can be promoted.

Synthesis

Chemical synthesis (or combination) is the artificial execution of chemical reactions to obtain one or more products as a science topic. Physical and chemical manipulations, usually involving one or more reactions, are used to achieve this. The procedure is repeatable and reliable in current laboratory settings.

A chemical synthesis entails the use of one or more substances (referred to as reagents or reactants) that undergo a transformation when exposed to specified conditions. To create a desired result, a variety of reaction types can be used. This necessitates the use of a reaction vessel, such as a chemical reactor or a simple round-bottom flask, to mix the chemicals.

The reaction yield is the amount produced by chemical synthesis. In a laboratory context, yields are usually represented as a mass in grams or as a percentage of the total theoretical quantity that could be generated based on the limiting reagent. A side reaction is a chemical reaction that occurs unintentionally and decreases the target yield. Hermann Kolbe, a chemist, was the first to use the term synthesis in a chemical context (Smith et al., 2013).

There are many more intricate chemical synthesis processes than merely turning a reactant A to a reaction product B. A chemical product is created in multistep synthesis by a sequence of separate chemical reactions, each with its own work-up. A laboratory synthesis of paracetamol, for example, can be broken down into three steps. Many chemical transformations occur inside a single reactant in cascade reactions, as many as 11 distinct reactants generate a single reaction product in multi-component reactions, and one reactant experiences multiple transformations without isolation of intermediates in telescopic synthesis.

Organic synthesis is a subset of chemical synthesis that focuses on the creation of organic molecules. Multiple methods in sequence may be necessary to synthesize the product of interest, requiring a significant amount of time. Organic synthesis is highly valued among chemists, and the creation of extremely valuable or complex chemicals has earned researchers such as Robert Burns Woodward the Nobel Prize in Chemistry. It is a totally synthetic process when a chemical synthesis begins with basic laboratory substances. If it starts from a product isolated from plants or animals and then proceeds to new compounds, the synthesis is described as a semisynthetic process.

Synthesis: Putting together different entities to make a whole which is new and different. In biochemistry, synthesis refers specifically to the process of building compounds from more elementary substances by means of one or more chemical reactions.

For example, the adipocyte is a cell that is specialized in the synthesis and storage of fat. Synthesis means to combine a number of Synthesis different pieces into a whole. Synthesis is about concisely summarizing and linking different sources in order to review the literature on a topic, make recommendations, and connect your practice to the research (Seil and Webster, 2012). Synthesis usually goes together with analysis because you break down a concept/idea into its important parts/points (analysis), so you can draw useful conclusions or make decisions about the topic or problem (synthesis).

Synthetic Method

The art of synthesizing organic compounds from smaller components is known as synthetic organic chemistry. This science has been used in the synthesis of commercially important organic compounds, the construction of new, potentially bioactive molecules derived from rational design, the challenge of synthesizing very complex natural products, and the development of new methods and strategies to make this science more efficient.

Synthesis is the process of creating chemical compounds from simpler components through chemical reactions. Building complex and defined new compounds is a difficult and time-consuming task that necessitates the ongoing invention of novel reactions, catalysts, and procedures.

Synthesis projects are at the heart of progress in a wide range of fields. Chemical synthesis is a unique and enabling science since it allows the design of novel molecules to be put into practice, allowing the target compounds to be created and examined for interesting features or activities.

Areas in which synthesis methods are essential:

- **Catalysts:** It is essential in a wide range of industrial processes, including the production of both bulk and fine chemicals. The creation of more efficient, selective, and environmentally tolerant processes requires the logical design, synthesis, and optimization of catalyst systems. This research focuses on both metal-containing and metal-free systems, and it aims to develop better catalysts for existing processes as well as completely novel catalytic transformations (Sawhney et al., 2008).
- **Drug Development and Medicine:** Organic synthesis plays a critical role in the development of novel medicinal drugs. This project allows for the development and optimization of complex compounds with potent and specific biological activity. Understanding synthetic chemistry enables the chemical properties of molecules to be balanced so that they behave as intended in cells and patients. Another important aspect of this effort is the invention of novel reactions, which opens up previously unavailable avenues to new molecules.
- **Brand-New Materials:** Preparation of functional materials with custom-designed features (e.g., electrical, optical, magnetic) is critical for advancements in fields like batteries, solar cell development, superconductors, smart materials, and other areas that offer a lot of promise for future technologies. The Department of Chemistry at Oxford has a long history in this field, having

performed the essential synthetic work that underpins lithium-ion battery technology.

- **Biological Chemistry:** The creation of molecules that interact with and probe biological systems is extremely valuable for studying and comprehending the processes that occur in living systems. Such chemicals help us better understand fundamental biological processes and enhance drug discovery by allowing us to validate targets more effectively.
- **Products Made from Natural Ingredients:** Natural products have always been important, as evidenced by the history of medicines, flavorings, and agrochemicals. Synthetic chemistry is extremely beneficial for replicating Nature and preparing complex chemicals that are formed naturally but without damaging the source. Natural goods, as well as analogs of them, have a wide range of applications as medications, flavorings, and agrochemicals (Figure 61).

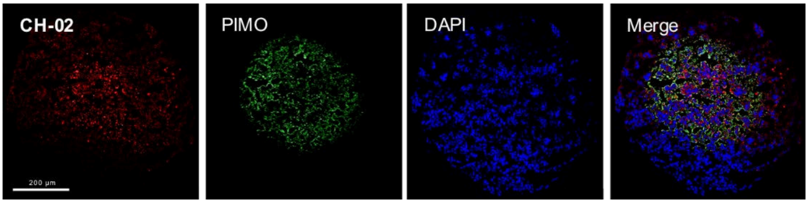


Figure 61. Microscopic imaging.

Source: https://www.chem.ox.ac.uk/sites/default/files/chem/images/media/synthesis-banner4.png.

Synthetic dyes and probes have played a critical role in recent advances in imaging, allowing for the employment of more powerful and less intrusive approaches in the hunt for sick or damaged tissue.

T

Transmission Electron Microscope (TEM)

Transmission electron microscope (TEM) is a special microscope that uses an electron beam to visualize samples and produce highly magnified images. TEM can magnify matter up to 2 million times. To get a better idea of how small it is, think about how small a cell is. No wonder TEM has become so valuable in biology and medicine. A TEM uses a high-voltage electron beam to create images. An electron gun at the tip of the TEM fires electrons to pass through the microscope’s vacuum tube. Instead of using glass lenses to focus light (like optical microscopes do), TEMs use electromagnetic lenses to focus electrons into very fine beams. This beam subsequently passes through a very thin sample and the electrons are scattered or hit a phosphor screen at the base of the microscope. An image of the sample appears on the screen, with different parts of it displayed in different shades according to their density.

Template

There are different definitions of the template depending on the context. The term template can also be used to refer to a file created with a general layout, which can be used in one or more documents. In this case, a template is also referred to as a design template. For instance, a program can have a template for a birthday card or a resume. In the case of a resume, the general layout is made using a placeholder text where one can replace with information relevant to the individual. A computer program may come pre-designed with the ability to allow the user to create a template. The user wants a template to suit their liking, then they have to create a customized template. After creating the customized template, the user can save, share, and reuse it. The customized templates may contain layouts, background styles, content, theme colors or theme fonts (Safari and Zarnegar, 2014). There are different kinds of design templates, all depending on the type of work that should be created though they bear similar themes and patterns throughout the work. For instance, a design template used in a photo gallery page will be different from the layout used in a story page with is in turn different from the contact page. There are different packages with templates. For instance, with Microsoft PowerPoint comes with design templates useful in providing a visual and cohesive organization in presentations. Each of the slides may have various graphics and layouts, through the general look exhibits continuity. There is custom-made templates used in Adobe InDesign, office, and design programs, Google Docs, and Microsoft Office Programs.

Templates are used in web design to help structure the general design of the web page. The user is given an area to place texts and pictures. Different companies offer different kinds of templates enabling the user easily create a website. A template is used in programming as the foundation for unique units of code. For example, in a program such as C++ there is a standard template library for which programmers can select individual the class to modify. The program is an object-oriented computing language and the template libraries help in attaining the goal. Another area where templates are used include nanotechnology. Nanotechnology makes use of template synthesis which is a cutting-edge technology developed in the 1990s. The technology is said to be used and effective in nanomaterials synthesis method used over the years. Among the methods used with nanomaterials is the template method. This method is less sensitive with regards to the conditions for preparation, ease of operation and implementation. The method is used in controlling the particle size, structure, and morphology of nanomaterials through a template. The method is divided into two, namely the soft template method and hard template method. Some institutes use the hard template method which involves the use of mesoporous carbon pellets as a template. The method is used in the synthesis of non-silicon-based mesoporous materials while the soft template method is used in the exploration of different types of organic and inorganic combinations.

Template Synthesis

Template synthesis is a technique used in the preparation of nanofibers within the pores of a solid or a microporous membrane. The microporous membrane is also called a template. A template is usually preconfigured to obtain a particular nanofiber morphology. The template synthesis process entails the use of a polymer template or a metal oxide having cylindrical pores of uniform diameter. One of the methods involves the template being placed directly on a current collector. Various processes are used in filling the nanoscale cylindrical pore with the material. Some of the processes include chemical vapor deposition (CVD), sol-gel, and electrodeposition. The template is removed after the nanofibers have been formed. This leaves the nanofibers adhered to current collector (Baruah and Dutta, 2009). A different method involves the utilization of applied pressure to extrude a polymer solution via the template. A precursor fiber solution gets into contact with a solidifying solution as it traverses through the pores. The contact process allows the precursor fiber solution to hold a cylindrical structure. The process is very similar to an extrusion process. The nanofiber morphology can be controlled through the manipulation of fiber material, processing parameters and template wall chemistry. Some of the processing parameters include temperature, soaking time, pH, and concentration. This allows the creation of hollow nanofiber also called nanotubes. Template synthesis is considered a versatile method for fabricating aligned nanostructures with desirable sizes.

4The templates or membranes used in temple synthesis are used in achieving desired structures. There are different kinds of templates, among them being the soft template. The soft template is made up of polymers or surface stabilizing molecules. There are also hard templates which use porous solid material like mesoporous silica and anodic aluminum oxide. When selecting templates, the porous alumina template is remarkably good. They are also considered an exceptional choice of material to be used in the production of nanofibers from various substances like ceramics, semiconductors, metals, carbon, and polymers. Precursor compound can be absorbed into the channels of a porous alumina through CVD or solution phase. Materials solidify through chemical reactions or thermolytic. The fibers separate due to the dissolution of the alumina membrane. To fabricate a new class of monolithic aerogel, a template-directed hydrothermal carbonization process was applied. The monolithic hydrogels are made of highly uniform carbonaceous nanofibers. While observing the SEM images, it is observed that the structure is a highly porous network having uniform size nanofibers interconnected to each other through several junctions.

The advantage of using template synthesis is that any electrochemical laboratory can get access to materials needed in the preparation of electrode systems with critical dimensions in the domain of nanometer. The utilization of microporous template presents a practical and attractive methodology useful in preparing different kinds of nanomaterials characterized by composites, conducting polymers, salt, metal oxides, and high aspect ratio. The nanomaterials exhibit peculiar and advantageous performances with extensive electrochemical applications. Some of the applications include them being used in energy storage and electro-analysis. When compared to other electrode systems, NEES exhibit a dramatically enhanced signal-to-background ratio useful in sensing and electro-analytical applications (Ravichandran, 2010). Templates have been used in the construction of nanostructured electrodes for batteries. This has been done with the aim of overcoming limitations of conventional electrochemical energy storage systems. It places more focus on improving the cyclability of electrode materials. NEEs are a good option in the creation of semiconductors. The materials could be very useful in light-harvesting applications in both electricity and fuel production. Nano electric materials show a longer length of electron diffusion thereby improving the overall efficiency by creating a direct charge transport pathway for the photo-generated. There is the possibility that NEEs could in future contribute to the development of highly miniaturized electrochemical systems which can be used in energetics and sensing purposes.

Thin Film

A thin film is described as a layer of material with thickness varying from fractions of a nanometer to numerous micrometers. The synthesis of materials in the production of thin films is referred to as deposition. The synthesis of these materials is controlled and considered a basic step in several applications. A basic example is the household mirror which consists of a thin metal coating on the back of a sheet of glass forming a reflective interface. Initially, the silvering process was usually used in the production of mirrors. With advancements being made over the years, the metal layer deposited uses techniques like sputtering. Thin-film techniques have become more advanced over the years and in the 20th century have allowed extensive technological breakthroughs in various fields. Some of the areas affected by the advancements include hard coatings on cutting tools, antireflective coatings, Leads, integrated passive devices, semiconductor devices, energy generation and storage and magnetic recording media. Thin-film deposition techniques are also used in pharmaceuticals through thin-film drug delivery. A multilayer is the term used for a stack of thin films. Other than their applied interest, thin films play a crucial role in the study and development of materials having new and unique properties (Presting and König, 2003). For instance, while studying quantum phenomena, superlatives, and multiferroic materials are used. In a bid to promote stronger adhesion, chromium, and titanium films are used as intermediate layers. Another area of application is in plasmonic and biosensor devices. Plasmonic structures consist of noble metal thin films. Examples of plasmonic structures include the surface plasmon resonance sensors. Surface waves in the optical regime that can propagate between metal-dielectric interface are the surface plasmon polaritons. While configuring the SPR via evaporation, a prism is coated with a metallic film. Chromium films, titanium, and germanium films are used to promote stronger adhesion by acting as intermediate layers. They help overcome the challenges of poor adhesive characteristics of metallic films. Plasmonic waveguide designs also make use of metallic thin films.

Thin films are also used in making thin-film photovoltaic cells. In a bid to reduce the cost of solar cells, much focus has been placed on the development of thin-film technologies. The notion is that thin-film solar cells are cheaper. This is attributed to the reduced costs on capital, handling, energy, and materialism. A better illustration is the use of printed electronics processes. Emerging photovoltaic cells are also known as third generation photovoltaic cells. They consist of thin-film technologies in the early stages of ongoing research. They could also be used to refer to thin-film technologies with limited commercial availability (Porter et al., 2008). They include perovskite, nanocrystal, copper zinc tin sulfide, quantum dot, organic, dye-sensitized, and polymer solar cells. Thin films are also used in making thin-film batteries where a thin-film pro ting technology is used in applying solid-state lithium polymers to a variety of substrates resulting in the creation of unique batteries. Thin-film batteries have extensive applications. They can be deposited directly into chip packages or chip in any size or shape. By printing onto paper, thin metal foil or plastic, one can create a flexible battery. They are also used in making thin-film bulk acoustic wave resonators. Piezoelectric crystals thin-film bulk acoustic resonators are used to allow precise control of resonance frequency. These resonators are developed for sensor, duplexers, telecommunication filters and oscillators applications.

Top-Down Molding

The top-down molding is a technique used in nanotechnology in designing materials. It is also referred to as the top-down approach. This method involved bulk materials being broken down into nanosized particles or structures. This method is said to be an extension of synthesis techniques used in the production of micron-sized particles. In other words, the top-down molding is a fabrication method that takes bulk materials and chips away at the material resulting in the formation of a material with a desired nano-pattern. This method of production is much simpler and dependent on the miniaturization of bulk fabrication processes or division or removal of bulk material in the production of desired structures with certain properties (Patil et al., 2008). The challenge of the top-down molding is the imperfection of surface structure. Take the case of nanowires made using lithography. They are not smooth and may have several impurities as well as structural defects on its surface. Examples of the top-down molding techniques include atomic force manipulation, electron beam lithography, high-energy wet ball milling and gas-phase condensation. Among the top-down Molding methods available for nanoscientist is etching. Etching is a method of removing a material via physical or chemical means. Etching can be done on surfaces of materials, and in the case of nanoscale etching, the two common methods include deep reactive ion etching and reactive ion etching.

The reactive ion etching can be classified under dry etching. It is a technique that etches the nanomaterial but using a bombardment of ions in the form of plasma. The plasma etchant is highly preferred to the liquid etchant. This kind of etching is performed in certain conditions. The environment has to be a vacuum. There should be an applied electronic field, radiofrequency waves and low pressure causing the ionization of gas molecules resulting in the formation of a plasma. Some electrons are removed from molecules within the plasma. The removed electrons move up and down the etching chamber and finally find their way to the surface of the nanomaterial. It is important to note that the applied external field does not affect the platform on which the nanomaterial. This causes a DC isolation inside the system.

The vacuum chamber therefore contains a highly positively charged plasma and a highly negatively charged substrate. This causes some lighter ions within the plasma to move towards the negatively charged nanomaterial. Collisions occur during the process which results in the nanomaterial being etched through chemical and kinetic interactions.

The reactive ion etching is different from the deep reactive ion etching. The deep reactive ion etching is more penetrative and makes use of slight modes of operation. Its etching process is faster compared to reactive ion etching. Like in reactive ion etching, a gaseous plasma is also formed in deep reactive ion etching. The only difference is that the gaseous plasma produced in DRIE is a highly dense plasma. The gaseous plasma is generated in the same manner as with the RIE. The high-density plasma is as a result of the radio frequency antenna. Also, the plasma inductively couples with each other. Alternating radio frequency magnetic fields are generated around the plasma. This causes the induction of radiofrequency electric fields which ionizes the plasma heavily (Pathakoti et al., 2018). When compared to RIE, a significant number of heavy ions were lost to the wall of the vacuum. However, in DRIE, the coupling nature of plasma ensures that heavy ions are not lost from the plasma contributing to the high density of plasma in DRIE. The nanomaterial sits on a plate connected to a separate radio frequency power source that induces a DC bias between the nanomaterial and plasma. Deeper etches are created because the highly-dense ions in plasma collide with the nanomaterial.

Lithography is also among the methods accessible by nanoscientist. It is used in removing portions of nanomaterials and also creating a pre-determined pattern on the surface of a nanomaterial. The technique is referred to as nanolithography (NL) methods when the materials used are specifically nanomaterials. A material is patterned to a desired form through an energy-intensive process of some description and varies from technique to technique. In some cases, the material needs to be protected because the goal is to form a specific pattern or geometry. Protection is needed to ensure that the material is not susceptible to total removal. A mask is used when a material needs protection. The mask contains properties relevant to protecting the material from the technique. The material under the mask will not be removed.

Toxicity

Toxicity is described as exposure to nanoscale materials through ingestion, breathing and skin penetration. The capacity of nanoparticles to diffuse throughout the body and their solubility are major concerns. Some nanoparticles diffuse easily, and have the same effect on living organisms as the chemicals that make them up. Nevertheless, other nanoparticles do not easily degrade or dissolve. Rather, they gather in biological systems and linger for long periods of time, which makes these nanoparticles of unique interest.

Nanotechnology is not exempted from the worry on toxicity with regards to the materials being used. Over the years, several advancements have been made in the field of nanotechnology with new and diverse applications of nanoparticles being discovered every day. The challenge is that there is limited information on the toxicity of nanoparticles and their effects on biological systems. Potential exposure routes of nanoparticles include dermal penetration, inhalation, and inhalation. The toxicity of nanoparticles can be defined by their surface chemistry, surface area, particle shape and particle size. Increased intentional and unintentional production of nanomaterials increase chances of exposure, thereby increasing the possibility of their adverse health effects. For this reason, it is essential that novel nanomaterials are biologically characterized for their health hazards. This is to ensure sustainable and risk-free implementation of nanotechnology. Some of the nanomaterials such as NPs are naturally occurring. Advancements have been made in the production and use. Engineered Naps have extensive applications in various areas such as water treatment, fuel catalyst, electronic catalyst, coatings, paints, bioremediation, food packaging, medicine, and cosmetics. The medical field have developed drugs encapsulated into nanoparticles. Due to the large surface area to volume ratio, the drugs are water-soluble, stable, and clump-free. Another application is Naps is the nanoparticle-mediated drug delivery which is used as a preventive treatment of oxidative damage implicated on various neurodegenerative diseases like Wilson’s disease. Nanoscientists are also looking into using novel nanomaterials in diagnostic and therapeutic applications in the diagnosis and treatment of cancer. In such a case, the nanoscale properties allow the entry and intercellular transport to certain target sites. Though nanomaterials are under investigation to establish their toxicity, they are used in minimizing the production of wastes as well as industrial contamination. They are also used to improve the efficiency of energy use and production. The extensive use of nanotechnology increases the potential risk of toxic release to the environment (Bohr, 2002).

There are those who argue that the use, production, and disposal of synthesized NPs may result in discharges in soul, air, or water. And it could lead to pollution; it is important to investigate how they move into and through the environment and the potential environmental and health effects. The challenge with nanomaterials is that there is indiscriminate use of nanoparticles whose toxicological properties may prove hazardous to human health, wildlife, and the environment. As stated earlier, there is limited knowledge of the hazardous effects of nanoparticles. For this reason, no regulations have been developed to control the use of nanoparticles.

There are those who view the toxicology of nanomaterials in the line of nanomedicine and nanotoxicology. Both nanotoxicology and nanomedicine are considered to be two sides of the same coin in that their value is linked to their use. The environment and human beings could get exposed to nanoparticles throughout their life cycle which starts from the manufacture and ends in disposal. The particles could get to the environment through permitted release or accidental release of industrial effluents in aquatic systems and waterways, which may lead to direct exposure to nanoparticles through direct ingestion of contaminated water or particles taken up by edible plants, inhalation of water aerosols and dermal contact. Nanoparticles can easily be taken up into cells because of their small size. Their small size also allows them to be translocated across endothelial and epithelial cells. They can also find their way into various parts of the body (Nikalje, 2015). Their stay in the body can be prolonged by the fact that they interact with body tissues. It is anticipated that a higher concentration of nanoparticles will be in bodies with high phagocytosis activity. Such organs include the spleen, kidney, and liver. The toxic effects could also be noted in the cellular, cutaneous, renal, reproductive, cardiac, and pulmonary level. For this reason, a precautionary approach is needed for the individual evaluation of new nanomaterials to reduce the potential risk to the health and environment linked to the use of nanomaterials in areas of application. The existing protocols can be applied when identifying any harmful effects linked to nanomaterials. There is need for new techniques which can address some unique properties of nanomaterials.

Transistor

A transistor is a three-terminal device with three distinct layers. Two of the terminals are doped to give the same type of semiconductor, while the third terminal is of the opposite type. For instance, two terminals may be of the n-type and one a p-type or one may be an n-type while two are p-type. This kind of arrangement has the two similar transistor layers sandwiching the layer of the opposite type. For this reason, semiconductor devices can be designated as NPN transistors or PNP transistors depending on the make. The three terminals can also be called electrodes. They are the collector, emitter, and base. The collector also known as the collector gain gets its name from the fact that it collects the charge carriers. The emitter gain or the emitter gets its name from the fact that it emits charge carriers, while the base of the transistor gain got its name due to the fact that in early transistors, this electrode was the base for the whole device (Mnyusiwalla et al., 2003). The early transistors had two pints placed in the base material forming the base connection hence its name. In ordinary transistors, the base region is relatively thin. This is very important as it ensures the proper working of the transistors. Currently, transistors are made with a base having a thickness of nearly 1 micrometer. By having the vase region of the transistor being thin, a transistor is able to function properly. There are those who define a transistor as two p-n junctions placed back-to-back. There are certain junctions placed in forward bias which include the base-emitter junction. The base-collector junction is reverse biased. If an external power source is connected to a transistor and a current made to flow in the base-emitter junction, the amount of current flowing in the collector circuit is very large though the base-collector junction has been reversed biased (Figure 62).

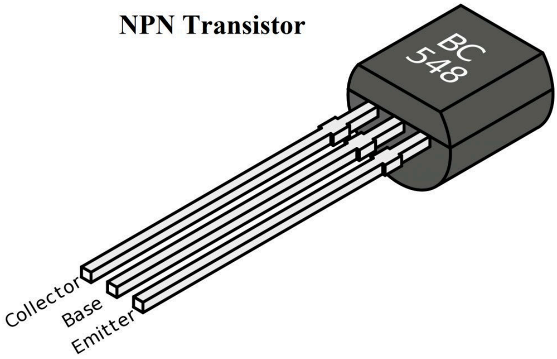


Figure 62. Transistor terminals consist of three parts which are the collector, base, and emitter.

Source: https://electronics-club.com/transistor-terminals-with-multimeter/.

There are two main types of transistors used in physics. They are the field-effect transistors and the bipolar junction transistor. In the field-effect transistor, the transistor has three terminals which include the gate, drain, and source. It also has a voltage gate which allows the control of current between the drain and the source while in the bipolar junction transistor current flowing between the emitter and base terminals is controlled by the base terminal. It is therefore correct to say that those transistors come in a variety of shapes and sizes. A common attribute in all kinds of transistors is that they have three leads. A commonly transistor used in devices is the bipolar junction transistor. It is characterized by three terminals each connected to doped semiconductor regions. There are two types of bipolar junction transistor, namely the N-P-N and the P-N-P. In a P-N-P transistor, the layer of N-doped semiconductor is between the layers of P-doped material. In such a transistor, current entering the collector is amplified in the output. When such a transistor is put on, the base is pulled low relative to the emitter. A P-N-P transistor symbol contains arrows (Morrow et al., 2007). The arrows indicate the direction of current flow when the device is in forward bias. For an N-P-N transistor is made up of a P-doped semiconductor sandwiched between two layers of N-doped material. There is a high collector and emitter current because the base current is amplified. When the transistor is put on, the base is pulled low relative to the emitter. Current flows between the collector and the emitter when the transistor is in on state. In the P-type we have electrons moving from the emitter to the collector due to majority carriers. This enables a fast operation while a large current is allowed to flow. This is why most bipolar transistors are NPN transistors.

The field-effect transistor is used in conduction. It could be a P-channel, N-channel, or a unipolar transistor. The field-effect transistor has three terminals namely the drain, gate, and source. In an N-channel FET, the transistor is constructed from n-type material and is found between the drain and source. The N-type material acts as a resistor. The FET is used to control negative and positive charge carriers concerning electrons or holes. When the positive and negative charge carriers move, an FET channel is formed. There are FET channels made of silicon. There are several types of FET's including MOSFET and JFET. Among the applications of FET's including analog switch, buffer amplifier and low noise amplifier.

The bipolar junction biasing occurs in several devices. Currently, almost every semiconductor active device has a transistor in their circuit. Amplifiers and electronic switches are among the devices having transistor. Transistors have different functions in electronic circuits. Basing in transistors is achieved by using resistor networks. A common term that pops up when using transistors is the operating point. This is the point on the output characteristics of a transistor that shows the collector current and collector-emitter voltage with no input signal. The operating point is also called the quiescent point or the bias point. Biasing is a term used to refer to the provision of supply voltage, capacitors, or resistor so as to provide proper operating characteristics of transistors. The DC collector current at a particular current voltage can be obtained using the DC biasing. Values of current and voltage can be expressed in terms of the Q-Point. The term VCE (max) is used to refer to the maximum voltage applied across a device while IC (max) is the maximum current that can flow through the transistor. A load resistor is connected to the collector for the transistor to work as an amplifier. The transmission electron microscope is a device that operates on based of optical principles. Its working is similar to that of a light microscope. The advantage of a TEM over a common light microscope is that it has a greater resolution. The greater resolution allows the study ultrastructure of macromolecules, viruses, and organelles. TEM can also be used to view specially prepared material samples. There are cases where the TEM and a light microscope are used together. An example of such a case is in a research project, which allows the two devices to complement each other. The electron beam is used in a vacuum environment as electrons are small in size and can easily be deflected by gas molecules or hydrocarbons. For the required vacuum to be achieved, a series of pumps are used to drive out the air. In the first series, rotary pumps are used. Also called the roughing pumps, rotary pumps are used to lower the pressure within the column in which the electron is required to travel to 10–3 mm of Hg range. The rotary pump is backed by the diffusion pumps (Mousavi and Rezaei, 2011). The diffusion pumps help the environment achieve higher vacuum. Other pumps used to create the vacuum environment include the Cryo, ion or turbopumps. They are usually backed by preceding pumps for greater vacuum. The light microscope and the TEM have the same organization. The TEM has an electron gun or an illumination source which works like a light bulb. The cathode works as the electron source and takes the form of a hairpin-shaped tungsten wire. The cathode cap has an accelerating voltage. For electrons to be released a small emission current is applied to the filament. The saturation point is defined as the point in which the gun achieves good thermal emission and an acceptable filament life. The cathode cap is another part of the TEM and is also called the Wehnelt cylinder. This part is usually more negative compared to the filament.

The bias knob is used to control resistors located in the gun assembly. This knob is used in creating the difference in negative voltage between the cathode cap and filament. It permits the collection of electrons inside the cap resulting in the formation of an electron cloud. Below the gun assembly is an anode and is electrically at ground. It creates a positive attraction for negatively charged electron. The electrons are then able to overcome the negative repulsion of the cathode cap. The electrons then accelerate through a small hole in the anode. The electrons can be impeded by a glass lens. This means that the electron microscope lenses are electromagnetic converging lenses. Copper wires are tightly wound to form a wrapping which makes up the magnetic field which is the essence of the lens. The coils are surrounded by a shroud made of a metal which will not hold magnetic charge when the lens is shut off. The center hole in the solenoid is a passage way for electrons. The pole piece further constricts the electron path. The constriction occurs due to the presence of a brass lining. The beam is most influenced by electromagnetic current in the small gap in the pole piece (Mitter and Hussey, 2019). Straight lines running through a convex lens are used to represent electron paths. It is more accurate to say that the electron paths form a tight spiral as electrons are accelerated through the lenses. The lens current influence the trajectory and path taken by electrons as they pass through a small opening in the lens. Condenser lenses in a TEM has the same functionality as condensers in light microscopes. For the first cross-over images to be done, the electrons are gathered and focused onto the specimen allowing the illumination of the area being examined. Spherical aberration can be reduced by using the condenser aperture. To focus the image, an objective lens is used. It can also be used in magnifying the image. For imaging purposes, the specimen stage is inserted into the objective lens. Close to the objective is the ant-contaminator also known as the cold finger. It is made up of a thin copper rod at liquid nitrogen temperatures causing contaminants to be attracted to it. It is required that the cold finger reservoir is filled with liquid nitrogen. In some cases, there are records of drift. Drift is a phenomenon caused by contaminants. It is defined as the apparent movement of specimen across the screen. The movement is caused by poor contact between the specimen holder and the grid resulting in the buildup of static charges and heat. The specimen contrast is enhanced by an objective aperture. Image from the objective lens is magnified by intermediate lenses. Image from the intermediate lens is magnified by the projector lenses. The resulting image is projected to the phosphorescent screen. The beam alignment is initially done before the TEM is used.

U

Universal Assembler

A universal assembler is used to manipulate and build within individual molecules, atoms, or other foundations. For this reason, it is referred to as a construction machine. It was first studied by John von Neumann, well known for his input in universal computers. Universal assemblers are those able to make any object. A universal assembler and a universal indicator are very similar in that they do not need a definite architecture. The device like automation is theoretically able to make full copies of itself if both energy and raw materials are provided. Its uses are not limited to self-replication. The uses of universal assemblers are limited to what the universal computer is able to generate. Nanotechnology has actively been involved in the creation of new forms of universal assemblers. Among the goals of nanotechnology is to conduct long-term research which will allow the production of programmable self-replicating universal assemblers. The theory behind self-replication is well understood by looking into Neumann probe designs and cellular automata (Mei et al., 2011). There are different names for universal assemblers with regards to the context. For instance, in fiction, universal assemblers are also called matter compilers, replicators or synthesizers. Universal assemblers are also found in nature in the sense that there are naturally existing self-replicators such as bacteria. Bacteria can be reprogramed to conduct particular tasks. Reprogramming can be achieved through genetic engineering. Over the years, different technologies that have been developed to help in the area of gene manipulation. Researchers have been able to insert certain proteins into a bacterium, thus changing its working. A good demonstration is the immune-system hormone interferon.

Universal Constructor

A universal constructor is also called a UC. It is a machine able to construct both macroscopic and microscopic objects. These machines rearrange substances at the atomic and molecular level and are able to create any physical object through this method. It can also be used in the creation of biological organisms. For normal individuals, universal constructors may seem to be very complicated considering the amount of work needed to create one. However, both the functionality and structure have not been established but the different components used in making universal constructors can be listed. Some of the vital aspects of universal constructors is their reaction modules. This was well demonstrated by Bob Page, who was actively involved in trying to convince Gary Savage to return the machines he stole. One of the important elements in a universal constructor is the containment unit. The schematic of the containment unit is called the molecular assembler. This means that it is the unit where raw materials are fed to the machine and are modified. Various devices make use of the containment unit. Within the device, the unit sorting and separating out the molecular feedstock. Examples of such devices are the sorting rotor cascade, electrically charged solenoids and the loffe trap. There are different models of a universal constructor. One of the models is VersaLife's universal constructor. This kind of universal constructor is the largest universal constructor and is found in Hong Kong VersaLife facility. The VersaLife's universal constructor is the only commercially used UC. The facility makes use of UC in the creation of augmentation canisters as well as the corresponding upgrade canisters (Marcato and Durán, 2008). Unbeknownst to a number of the staff members, VersaLife uses the Universal Constructor in the creation of the Gray Death nano-virus and its temporary vaccine called Ambrosia. Though VersaLife tries to keep all their research projects secret, the existence of the universal constructor is all over the world and practically every engineer in the world.

Utility Fog

Utility fog deals with the concept of robots. The concept of self-replicating robots forms the foundation of nanotechnology and utility fog is the extension of the idea. The ideology is that instead of building an object atom by atom, tiny robots could link their arms together resulting in the formation of a solid mass with desired shape and size and if one gets tired of the Avant-garde coffee table, a command is given to the robots making them shapeshift forming an elegant coffee table of desired shape, size, and look.

The properties of the robots will influence the reflectivity and color of the object. The properties are subject to the antenna in the micron wavelength region. This means that a single robot could possess an antenna arm that can be manipulated so as to Cary the properties making the surface of the utility fog object to almost resemble the picture the individual wanted. There are extensive applications of the utility fog. For instance, a thin film of robots could be used as a video screen by varying their optical properties in real-time. Rather than painting walls, they can opt to coat the walls with utility fog as they can change their color on a daily basis. They can also be used as a ceiling or any part of the house. A better option would be to make the entire wall out of fog and the floor plan can also be changed to better fit the occasion. Utility fog is a good flooring option so that when it gets dirty it will resemble hardwood but the texture is that of foam rubber. An entire domestic environment can be designed and achieved by using a utility fog (Figure 63) (Bhattacharyya et al., 2009).

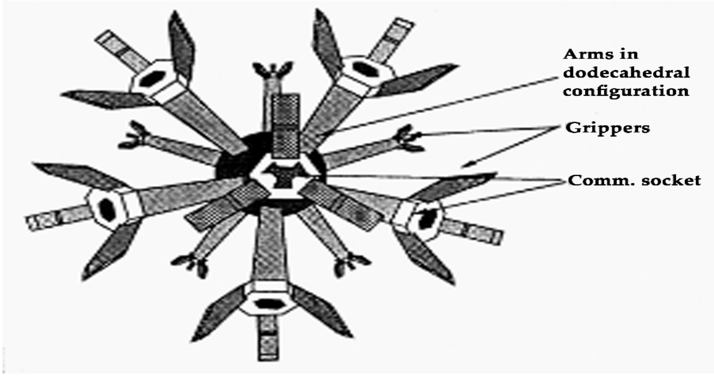


Figure 63. Internal structure of a utility fog.

Source: https://www.seminarppt.in/2014/02/utility-fog.html.

Utility fog is not limited to the house, it can also be used in cars creating a new look every day. Cars made using utility will have its interior made of robots. For one to see the robots, they will have to put on eye-phones though the fog will hold the robots in front of the driver's eyes. Compared to air, fog is heavier. Fog used in this case is programed to possess the physical properties of air. This means that it cannot be felt. In light of an accident, the fog creates an instant form-fitting seatbelt which protects every part of the body. More advancements are being made to create even more sophisticated models of the utility fog.

UV/Vis (Ultraviolet-Visible) Spectroscopy/Spectrophotometry

The ultraviolet-visible spectroscopy is a technique widely used in numerous areas of science. These areas include nucleic acid purity checks and quantitation, drug identification and bacterial culturing. It is also used in the food industry in controlling the quality of beverages in the beverage industry as well as chemical research. UV-Vis spectroscopy is defined as an analytics technique used to measure the amount of discrete wavelengths of visible or ultraviolet (UV) light which can be absorbed by a sample or transmitted through a sample while making comparisons to a reference sample. Sample composition influences this property and is vital in providing information on what the sample contains and the level of concentrations of the element. This technique is based and relies on the use of light. For us to better understand it, we need to look into the properties of light. Light contains a certain amount of energy said to be inversely proportional to the wavelength. This means that when the wavelength is short, the light will carry more energy and the energy carried is very low when the light has a very large wavelength. This means that a certain amount of energy is needed in promoting electrons in a substance from the ground state to s higher energy state (Manjunatha et al., 2016). At the high energy state, the electrons can be detected as absorption. To promote electrons to a higher energy state, different amounts of energy is needed because electrons have different bonding environments, each with certain energies that will cause the promotion. This explains why the absorption of light takes place at different wavelengths for different substances. Light is therefore described by its wavelength and is very useful in UV-Vis spectroscopy in the identification and analysis of various substances. The instrument used works by locating the specific wavelength which corresponds to the maximum absorbance. The instrument also makes use of a variety of filters. They include the cut-off filters, bandpass filters, interference filters and absorption filters. The absorption filters are mostly made of plastic or colored glass and is designed to absorb certain wavelengths of light. Interference filters are the most used filters and are composed of several layers of dielectric materials (Bowman and Hodge, 2007). Interference takes place between the thin layers of materials. This kind of filter allies the elimination of undesired wavelengths by utilizing the concept of destructive interference. They can be used as wavelength selectors. The band-pass filters allow a certain range of wavelengths to pass through. Their implementation requires the combination of both long pass and short pass filters. Finally, there is the cut-off filters. This kind of filter allows light which is either a long pass or a short pass of a specific wavelength to pass through. Interference filters are used in their implementation. It is very important for one to have the knowledge of the conditions and materials used in UV-Vis spectroscopy. In most experiments, quart sample holders are used in UV examination. This is because quartz is transparent to most UV light.

V

Vasculoid

The vasculoid concept arose from a basic question: Could we replace blood with a single, complicated robot once mature molecular nanotechnology becomes available? All critical thermal and biochemical transport capabilities of the blood, such as the circulation of breathing gases, waste products, cytokines, hormones, glucose, and all necessary cellular components, would be duplicated by this robot. The device would adapt to existing blood vessel shapes. In an ideal world, it would completely replace natural blood, leaving the rest of the body physiochemically unaltered while maintaining a cardioplegic state. It is essentially a mechanically built redesign of the human circulatory system that tries to incorporate itself as an intimate personal appliance with minimum adaption on the host human body (Contreras et al., 2017). A "vasculoid," or vascular-like machine, is a robotic device that substitutes and expands the human vascular system. The vasculoid, on the other hand, is more than just a man-made vascular system. Rather, it belongs to a category of space- or volume-filling nanomedical augmentation devices that work on the human vascular tree. With 500 trillion independent collaborating nanorobots, the device is very sophisticated. The vasculoid is a waterproof layer of nanomachinery dispersed across the luminal surface of the entire human vascular tree in its most basic form (Figure 64).

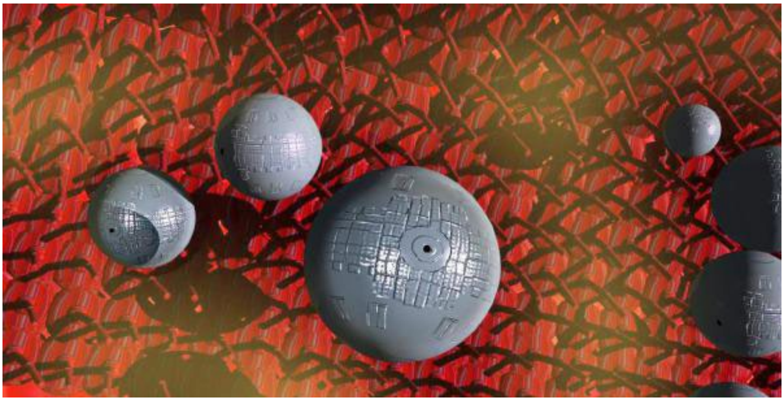


Figure 64. The vasculoid system is made up of an active, controlled lining that coats the surface of all blood vessels and is equipped with cilia that may waft fluids, encapsulated materials, and gadgets through the fluid-filled channels to any area of the body.

Source: https://www.orionsarm.com/eg-article/503e341570f73.

The benefits of placing a vasculoid could be considerable. Many of these advantages might conceivably be achieved with terabot-quantity dosages of much less aggressive bloodborne nanomedical devices on a short or limited basis. The vasculoid appliance, on the other hand, gives all of these benefits on an almost permanent and whole-body basis. Furthermore, some advantages appear to be unique to the vasculoid and cannot be obtained in any other method.

The ability to keep parasites, bacteria, viruses, and metastasizing cancer cells out of the bloodstream, thereby limiting the spread of bloodborne disease, is a significant benefit. The elimination of such microorganisms and cells from the blood can be accomplished with cm^3 doses of appropriately programmed nanobiotics, but such individual nanorobotic devices are unlikely to be used on a long-term basis. When infected cells are conveyed via the vasculoid, intracellular pathogens that can infect motile phagocytic cells (e.g., tuberculosis Mycobacterium or the bacterium Listeria, both of which can live inside macrophages) cannot be immediately eliminated from the tissues (Lü et al., 2009).

Another benefit is significantly quicker and more dependable lymphocyte trafficking all through secondary lymphoid organs, enabling them to survey for specific target antigens in minutes or hours instead of days (due to the efficient concentration of both white cells and antigenic sources), greatly speeding up the natural immune system response to foreign antigen. Individual histomobile medical nanorobots or biorobots could also supplement or replace lymphocyte function.

Reduced vulnerability to many types of chemicals, biological, and parasite toxins, including allergic chemicals in food, air, and water, but pharmacies, nanotankers, or bloodborne may be able to partially imitate this function. Toxins, novel metabolites, and other unfamiliar foreign materials may enter the tissues via solvents permeating the dermis (e.g., DMSO) or other nonvascular pathways, and would be eliminated from the natural blood in due course by the kidney, which by default retrieves all small molecules and then actively reabsorbs only beneficial molecules like sugars, electrolytes, water, and vitamins.

A biont's use of a vasculoid system is usually undetectable from the outside; the biont does not require a heartbeat or pulse, although both can be faked if necessary. In reality, most designs include a simulated pulse effect, which aids in the maintenance of the cellular and extracellular milieu in surrounding tissue. However, because a vasculoid system allows a user to go without breathing for extended periods of time while also allowing them to survive a variety of serious injuries, it is popular among bionts who engage in high-risk activities.

Vesicles

Gas vesicles are produced by a variety of bacteria and archaea to aid with flotation. These gas vesicles have been isolated from a variety of species, and their biotechnological and medical uses are discussed here. Antigens from eukaryotic, bacterial, and viral pathogens have been engineered into Halobacterium sp. NRC-1 gas vesicles. Both in vitro and in vivo, the capacity of these recombinant nanoparticles to elicit an immunological response has been assessed. As an acoustic reporter system, these gas vesicles, along with those isolated from Anabaena flos-aquae and Bacillus megaterium, have been produced. When exposed to ultrasound, this device uses the property of gas vesicles to retain gas within a solid, stiff structure to induce contrast. The ability of gas vesicles to collapse when subjected to too much pressure has also been postulated as a biocontrol mechanism for dispersing cyanobacterial blooms, implying that these structures have an environmental role (Chauhan et al., 2012).

Cell-to-cell communication based on extracellular vesicles is seen in all kingdoms of life. Extracellular vesicles are implicated in major (patho)physiological processes such as cellular homoeostasis, infection dissemination, cancer formation, and cardiovascular disorders, according to persuasive evidence. Extracellular vesicles, according to much research, have several benefits over typical synthetic carriers, opening up new avenues for modern drug administration. Clinical translation of extracellular vesicle-based medicines remains difficult despite substantial study. The peculiarity of extracellular vesicles is discussed here, as well as the crucial design and development procedures required to fully exploit their potential as drug carriers, such as loading methods, in-depth characterization, and large-scale manufacture.

While engineers and scientists have tried to use Vesicles' unique features to design smart drug delivery systems that outperform synthetic nanocarriers in terms of targeting, tolerability, and pharmacokinetics, clinical translation of Vesicles remains a challenge. The associated dangers of the manufacturing process are greater than those of completely synthetic production systems due to the complex nature of the Vesicles themselves, size heterogeneity, and natural (batch-to-batch) variability observed during their manufacture.

Vapor Deposition

CVD is a vacuum deposition technology for producing high-quality, high-performance solid materials. Thin films are frequently produced using this method in the semiconductor sector. Typical CVD involves exposing the wafer (substrate) to one or more volatile intermediates, which react and/or degrade on the substrate surface to form the desired deposit. Volatile by-products are frequently formed, which are eliminated by the reaction chamber's gas flow.

CVD is frequently used to produce conformal coatings and modify substrate surfaces in ways that other surface modification techniques cannot. CVD is particularly useful for producing incredibly thin layers of material in the atomic layer deposition (ALD) technique. Such videos can be used in a variety of ways. Some integrated circuits (ICs) and solar devices contain gallium arsenide. In photovoltaic devices, amorphous polysilicon is employed. Wear resistance is conferred by some carbides and nitrides (Chen and Yada, 2011).

CVD polymerization, possibly the most flexible of all applications, enables super-thin coatings with a variety of desirable properties, including lubricity, hydrophobicity, and weather resistance, to mention a few. Metal-organic frameworks, a type of crystalline nanoporous material, have recently been shown to be CVD-able.

The uses for these films are expected in gas sensing and low-k dielectrics, and they have recently been scaled up as an integrated cleanroom process depositing large-area substrates. Membrane coatings, like notably those used in desalination or water treatment, benefit from CVD processes because they can be uniform (conformal) and thin enough not to clog membrane pores.

Virtual Reality System

Nanotechnology and virtual reality technologies cross in a variety of ways. Nanotechnology involves the use of technologies that are downsized and small enough to be dubbed nanoscale, which ranges from 1 to 100 nanometers in size, with a nanometer equaling 1 billionth of a meter. One use of nanotechnology in virtual reality is the creation of long-lasting battery life for virtual and other reality — augmented reality or mixed reality — technologies without the need to recharge them on a regular basis. The potential to better maximize battery life as well as the size of the battery itself comes from understanding materials at a nanoscale level.

Nanotechnology improves the realism and immersion of virtual and augmented reality experiences on the display side. Manufacturers can benefit from nanotechnology innovation by achieving improved resolution and viewing angles. Within the small screen sizes utilized in virtual and augmented reality devices, manipulating viewing angles, light levels, and resolution is extremely difficult. The optics that render the encounter more realistic for users are technologically demanding, especially given the broad area that serves as the sensor input playing field when utilizing, say, an augmented reality headset. Because the data transfer protocols required by virtual reality, like 5G, are dependent on improvements in nanotechnology, nanotechnology can help create improved resolution in display technology (Doubleday, 2007).

Location sensors, optical sensing, sound, vibration detection, gyroscopes, inertial measurement units, accelerometers, and other types of environmental sensing are among the nanosize sensors used in augmented, virtual, and mixed reality systems. Even though many of these sensors are currently widely used, there is still a lot of room for them to be used on a nanoscale for integration and processing all of the data collected from sensors in an augmented or virtual reality system. Nanotechnology can also help to improve communication capacities (Figure 65).

Figure 65. Virtual reality is most commonly experienced on computers or smartphones running mobile apps as 3D graphics, photos, or 360° movies. Wraparound computer displays or even entire rooms with high-resolution displays incorporated into the walls are used in more advanced VR systems.

Source: https://www.nbcnews.com/mach/amp/ncna857001.

Nanotechnology can bridge gaps between processors and input environments to produce seamless, responsive communication between diverse parts of virtual reality. Simply said, human contact with sensors is required for augmented and virtual reality. These sensors use motion tracking or computer vision to interpret gestures, and then translate the motions into commands for the reality systems' processors. We might be able to see anything in our headsets that corresponds to the gesture in reaction to these commands. It is like selecting a film to watch on our augmented reality headset with a thumbs-up hand motion (Ehdaie, 2007).

The most serious issue with virtual reality is the limited space available for sensors, displays, batteries, and computers. The most difficult aspect of creating a portable, intelligent device is putting it together in a way that is not cumbersome. Nanotechnology advancements are continually decreasing the size of hardware while ensuring that it remains unharmed throughout daily use. Consider how many times you have dropped your TV remote and it has not broken.

Virus

The use of viruses as a supply of nanoparticles for biomedical reasons is known as virus nanotechnology. Viruses consist of a genome and a capsid, with some being enclosed. The majority of virus capsids have a diameter of 20–500 nm. Viruses have been classified as naturally occurring nanoparticles due to their nanoscale size dimensions. Nanoscience and nanoengineering have been used to study virus nanoparticles. Viruses can be thought of as nanoparticles that have been constructed. For instance, mammalian viruses are being researched as vectors for gene transfer, while bacteriophages and plant viruses have been used in drug delivery and imaging purposes, as well as vaccinations and therapeutic intervention.

Virus nanotechnology is one of nanotechnology's most promising and developing fields. Viral nanotechnology is a truly interdisciplinary area that sits at the intersection of virology, biotechnology, chemistry, and materials science. The field uses viral nanoparticles (VNPs) and their counterparts, virus-like nanoparticles (VLPs), for possible applications in a variety of sectors, including electronics, sensors, and, most importantly, medicine. For a variety of reasons, VNPs, and VLPs are appealing building blocks (Farokhzad and Langer, 2009).

Viruses have long been investigated as disease-causing pathogens in all living things. In addition to diseases, researchers began to think of viruses as tools in the 1950s. Bacteriophage genomes and components of the protein expression machinery have long been used as tools for gaining a better knowledge of cellular processes. Several viruses have been used as expression systems in biotechnology as a result of these investigations. Viruses are exploited as a vector for the benefit of humans later in the 1970s. Since then, viruses have frequently been utilized as vectors in agriculture and medicine for gene therapy, cancer control, and the control of hazardous or detrimental species.

Von Neumann Machine

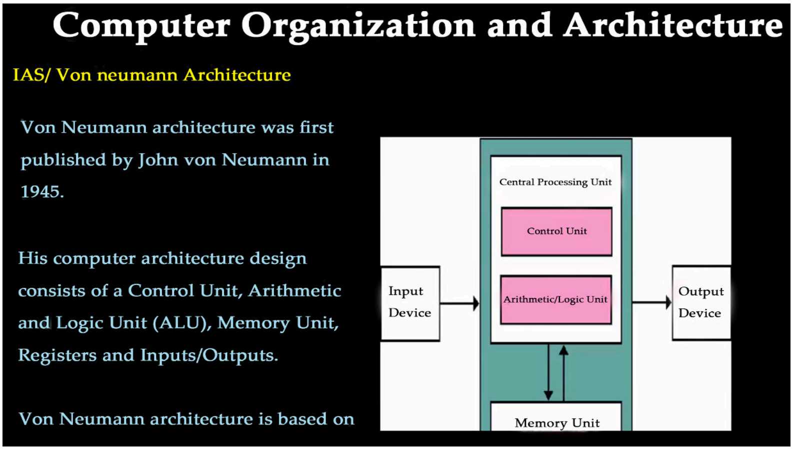
The phrase "von Neumann architecture" has come to refer to any stored-program computer in which a data operation and an instruction fetch cannot occur at the same time due to a shared bus. This is known as the von Neumann bottleneck, because it frequently limits the system's performance. A von Neumann architecture machine has a simpler design than a Harvard architecture machine, which is a stored-program system with one specialized set of address and data buses for reading and writing to memory and another set for fetching instructions.

Both program instructions and data are stored in read-write, random-access memory in a stored-program digital computer (RAM). The Colossus and the ENIAC, which were program-controlled computers of the 1940s, were replaced by stored-program computers. To transfer data and control signals between diverse operational units, those were programed by configuring switches and inserting patch cables. The large majority of current computers utilize the same memory for program and data instructions, but they include caches between the CPU and memory, with distinct caches for instructions and data in the caches nearest to the CPU, such that most instruction and data fetches utilize separate buses (Gupta, 2011).

Assemblers, loaders, linkers, compilers, and other automated programming tools are all made feasible by the capacity to handle instructions as data on a large scale. It enables "programs that write programs." A sophisticated self-hosting computing ecosystem has sprung up around von Neumann architecture devices as a result of this. Some high-level languages take advantage of the von Neumann architecture by offering an arbitrary, machine-independent way to change executable code at runtime (e.g., LISP) or by tuning just-in-time compilation using runtime information (e.g., languages hosted on the Java virtual machine, or languages embedded in web browsers). On a lesser scale, just-in-time compilation approaches can speed up some repetitive tasks like BITBLT or pixel and vertex shaders on general-purpose processors. This is one of the most well-known applications of self-modifying code.

Von Neumann Bottleneck

The von Neumann bottleneck theory states that computer system throughput is restricted due to CPU capability in comparison to data transfer rates at the upper end of the spectrum. The processor sits idle for a set length of time while memory is accessible, according to this explanation of computer architecture. The von Neumann bottleneck is titled after John von Neumann, a pioneering mathematician, researcher, and computer scientist who was also active in the Manhattan Project in the 20th century (Figure 66).



Computer Organization and Architecture

IAS/ Von neumann Architecture

Von Neumann architecture was first published by John von Neumann in 1945.

His computer architecture design consists of a Control Unit, Arithmetic and Logic Unit (ALU), Memory Unit, Registers and Inputs/Outputs.

Von Neumann architecture is based on

Figure 66. The von Neumann bottleneck theory states that computer system performance is strictly limited to processor capability in comparison to top data transfer speeds. A CPU is idle for a set amount of time while memory is accessible, according to this definition of computer architecture.

Source: https://www.youtube.com/watch?v=Z4AvPVffNM0.

The von Neumann bottleneck examines ways to provide faster memory access to a faster CPU. The von Neumann bottleneck is caused in part by the von Neumann architecture, in which a computer stores both programming instructions and actual data, as opposed to the Harvard architecture, in which these two types of memory are stored separately. As older, preprogrammed devices gave way to newer computers that required better ways to manipulate programming and data, these types of configurations were necessary (Gunasekaran et al., 2014).

The von Neumann bottleneck has been addressed by computer scientists in a variety of methods. One option is to store vital data in a cache that is immediately accessible. Multithreading, or managing numerous processes in a triaged system, is another option. Other potential solutions, such as parallel processing or modifying the memory bus design, aim to reduce the "bottleneck" or, to use a word typically used with this problem, enhance the bandwidth for memory entering and exiting the CPU.

Other “fixes” for a von Neumann bottleneck are more abstract. Experts have proposed a number of “non-von Neumann” or “non-von” systems, some of which are modeled by biological systems, that would allow for more distributed memory intake than the linear system utilized in traditional computing (Huang et al., 2010). Other developing technologies are used in some of the proposals, such as a “memristor” or other nanoscale component that aids memory processing. The range of viewpoints on the von Neumann bottleneck demonstrates how important this concept is in assessing computing’s potential as it has evolved over the previous few decades.

W

Wet Nanotechnology

Working up to huge masses from small ones is the goal of wet nanotechnology (also known as wet nanotech). Wet nanotechnology necessitates the presence of water in the process. Chemists and biologists are also involved in the process, which entails bringing together individual molecules to achieve bigger scales. While Eric Drexler proposed the idea of dry nano-assemblers, wet nanotech appears to be the most likely initial area where something like a nano-assembler may attain commercial success. Many nanotech start-ups are focused on pharmaceuticals and bioscience. Richard A.L. Jones refers to biokleptic nanotechnology as nanotechnology that takes parts of natural nanotechnology and puts them in a synthetic structure. Biomimetic nanotechnology is what he calls creating using synthetic materials that mimic nature's design principles. Using these concepts, trillions of nanotech robots with structural features similar to bacteria could enter a person's bloodstream to perform medical treatments (Kandel et al., 2013).

Wet nanotechnology is an upcoming new sub-discipline of nanotechnology that will be controlled by various types of wet engineering. The procedures will take place in aqueous solutions and are quite similar to those employed in biotechnology and bio-molecular manufacturing, which is primarily concerned with the creation of biomolecules such as proteins and DNA/RNA. Because living things are inherently bottom-up engineered, there is some overlap between Biotechnology and Wet Nanotechnology. Any manipulation of this by biotechnologists means they dabble in bottom-up engineering.

Wet nanotech, on the other hand, aims to analyze living things and their components as engineering systems in order to fully comprehend them and derive principles and methods that can be applied more broadly to bottom-up manufacturing, manipulating matter on the atomic and molecular scales, and fabricating machines and devices at the nanometer and microscopic scales.

Biotechnology is primarily concerned with utilizing living systems in any way feasible. The process of functioning of proteins in particular – and nucleic acids to a lesser extent – is compared to that of "molecular machines" in Molecular Biology and related sciences. Engineers must look into bottom-up manufacturing in order to replicate these tiny machines in a way that can be produced with some efficiency. Bottom-up manufacturing is concerned with altering individual atoms during the production process such that their location and interactions may be completely controlled (Kaur et al., 2014).

Then, starting at the atomic level, nanomachines might be created and even programed to self-replicate, as long as they are created in an environment with plenty of the necessary elements. Bottom-up manufacturing is sometimes known as "atom by atom" production since individual atoms are altered in the process. There could be a significant economic and social impact if nanomachine manufacturing can be made more accessible through improved procedures.

Biomimetics, according to both scientists and engineers, is an excellent way to begin thinking about developing nanoscale devices. Humans have only had a few 1,000 years to study the mechanics of things on extremely small scales. Nature, on the other hand, has spent millions of years honing the design and functionality of nanomachines. This is why nanomachines like ATP synthase, which work in human bodies and have a 95% efficiency, are currently in use.

X

X-Ray Analysis

X-ray analysis is a materials science technique for determining a material's crystallographic structure. It is a technique that involves irradiating a material with incoming X-rays and then measuring the intensities and scattering angles of the X-rays that exit the substance. The classification of materials based on their diffraction pattern is one of the most common applications of XRD analysis. XRD gives data on how the actual structure differs from the ideal one due to internal tensions and flaws, in addition to phase identification.

X-rays are waves of electromagnetic energy, whereas crystals are regular arrays of atoms. The interaction of incident X-rays with the electrons of crystal atoms scatters incident X-rays. Elastic scattering is the name for this phenomenon, and the electron is the scatterer. The scatterers in a regular array produce a regular array of spherical waves. These waves cancel each other out in most directions due to destructive interference, but they add constructively in a few select directions, as indicated by Bragg's law (Kung and Kung, 2004).

It is also known as X-ray crystallography, and it is an empirical science that determines the atomic and molecular architecture of a crystal by causing a beam of incident X-rays to refract in many different directions due to the crystalline structure. A crystallographer can create a three-dimensional picture of the density of electrons within the crystal by measuring the angles and intensity of these diffracted beams. The mean locations of the atoms in the crystal, as well as their chemical bonds, crystallographic instability, and other data, may be derived using this electron density (Figure 67).

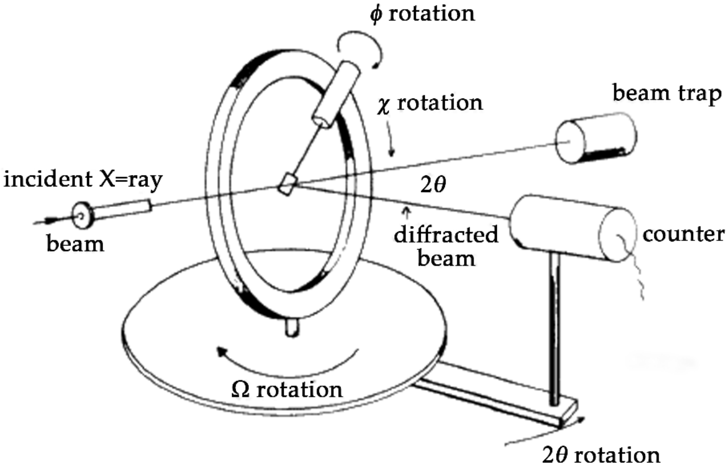


Figure 67. X-rays of a single crystal diffraction is a non-destructive analytical approach for obtaining precise data about the internal lattice of crystalline substances, such as unit cell dimensions, bond lengths, bond angles, and site-ordering data. Single-crystal optimization, in which the data provided by X-ray analysis is interpreted and refined to determine the crystal structure, is strongly attributable.

Source: https://serc.carleton.edu/research_education/geochemsheets/techniques/SXD.html.

X-ray crystallography has been essential in the development of many scientific domains since many materials may form crystals, including salts, metals, minerals, semiconductors, and other inorganic, organic, and biological molecules. This method was first used to estimate the size of atoms, the lengths and types of chemical bonds, and the atomic-scale differences between diverse materials, particularly minerals and alloys, in the early decades of its use. Many biological compounds, including vitamins, medicines, proteins, and nucleic acids like DNA, had their structure and function exposed by this technology.

X-ray crystallography is still the most common approach for determining the atomic structure of novel materials and distinguishing materials that appear to be similar based on other tests. X-ray crystal structures can also explain a material's peculiar electrical or elastic properties, throw insight on chemical interactions and processes, and serve as the foundation for developing disease-fighting medications. A crystal is put on a goniometer in a single-crystal X-ray diffraction measurement. The goniometer is used to place the crystal in various positions (Klimeck et al., 2008). The crystal is lit with a monochromatic X-ray beam that is tightly focused, resulting in a diffraction pattern of regularly spaced spots called reflections. Using the mathematical method of Fourier transforms (FTs), together with chemical data for the sample, the two-dimensional pictures acquired at various orientations are turned into a three-dimensional model of the density of electrons within the crystal. If the crystals are too small or their internal makeup is not homogeneous enough, poor resolution (fuzziness) or even mistakes can occur.

X-ray crystallography is linked to a number of different atomic structure determination techniques. Scattering electrons or neutrons generate similar diffraction patterns, which are also understood by Fourier transformation. If single crystals of suitable size cannot be acquired, additional X-ray methods such as fiber diffraction, powder diffraction, and small-angle X-ray scattering can be used to obtain less detailed information (SAXS). If the material under research is only available in nanocrystalline (NC) powder form or has poor crystallinity, electron crystallography methods can be used to determine the atomic structure.

X-Ray Diffraction

X-ray diffraction is a process in which the atoms of a crystal generate an interference pattern of the waves existing in an incident beam of X rays due to their equal spacing. The crystal's atomic planes act on the X rays in the same way that an evenly governed grating does on a beam of light. When a monochromatic X-ray beam interacts with a target material, the scattering of those X-rays from atoms within the target material is the dominating effect. The scattered X-rays interfere constructively and destructively in materials having regular structure (i.e., crystalline). This is the diffraction process. Bragg's Law, n(lambda) = 2d sin, describes the diffraction of X-rays by crystals (theta). The size and form of the material's unit cell determine the available diffraction orientations. The kind and arrangement of atoms in the crystal structure determine the intensity of diffracted waves (Lakhal and Wood, 2011).

Most materials, on the other hand, are polycrystalline aggregates or powders, which are made up of many small crystallites in all possible orientations. When an X-ray beam is focused on a powder with randomly oriented crystallites, the beam will observe all potential interatomic planes. All conceivable diffraction peaks from the powder will be recognized if the experimental angle is consistently varied. The most common geometry for diffraction devices is the parafocusing (or Bragg-Brentano) diffractometer.

High resolution and high beam intensity analyzes are possible with this geometry, but it comes at the cost of highly perfect alignment and well-prepared samples. Furthermore, the source-to-sample distance must be constant and equal to the sample-to-detector distance in this geometry. Alignment faults can cause problems with phase identification and quantification. Unacceptable specimen displacement errors can result from a misplaced sample. In-line sample measurement is impossible due to sample flatness, roughness, and placement restrictions.

Traditional XRD systems also use cumbersome equipment with high power requirements, as well as high-powered X-ray sources to enhance X-ray flux on the sample, which increases the observed diffraction signals from the sample. Large excitation regions are another disadvantage of these sources for diffraction investigation of small samples or small sample features. Many of these disadvantages and constraints can be overcome using polycapillary X-ray optics to improve XRD applications (Lieber, 2003). A highly divergent beam is converted into a quasi-parallel beam with minimal divergence using polycapillary collimating lenses. They may be utilized to create a Parallel Beam XRD instrument geometry that considerably minimizes and eliminates many of the parafocusing geometry's causes of peak position and intensity errors, such as sample position, shape, roughness, flatness, and opacity.

Z

Zeptosecond

For the first time, laser physicists in Munich have recorded a photoionization — when an electron quits a helium atom after being excited by light — with zeptosecond precision. A zeptosecond (10–21 seconds) is a trillionth of a billionth of a second. This is the most precise time measurement ever made, as well as the first absolute determination of the photoionization timeframe. To see what happens when light strikes the two electrons of a helium atom, one must be extremely fast. Aside from the ultra-short timescales in which changes occur, quantum physics is also involved (Presting and König, 2003).

For the first time, laser physicists from the Max Planck Institute of Quantum Optics (MPQ), the Technical University of Munich (TUM), and Ludwig Maximilians University (LMU) Munich have recorded such an event with zeptosecond precision. If a photon strikes the two electrons of a helium atom, either the entire energy of the photon can be captured by one of the electrons or a division can occur. One electron departs the atom regardless of the energy transfer. This phenomenon is known as photoemission, or the photoelectric effect, and it was first described by Albert Einstein around the turn of the century.

Laser physicists have developed a new measurement approach that allows them to properly measure events at a pace of up to 850 zeptoseconds. To excite the electrons in a helium atom, the researchers used an attosecond-long, extremely ultraviolet (XUV) light pulse. They also fired a second infrared laser pulse, lasting around four femtoseconds, at the same time (Manjunatha et al., 2016). The infrared laser pulse detected the electron as soon as it left the atom after being excited by XUV light. The electron was accelerated or decelerated depending on the particular electromagnetic field of this pulse at the time of observation. The physicists were able to measure photoemission with zeptosecond precision thanks to this variation in speed.

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Encyclopedia of Nanotechnology

Nanotechnology has accomplished a lot in just a few years. It is evident that nanotechnology will change dentistry, medical care, and human life more significantly than numerous technologies of the past. Likewise with all advancements, nanotechnology conveys a critical potential for misuse on a scale and extent never seen. However, they likewise can possibly achieve critical benefits, like improved wellbeing, better utilization of natural resources, and reduced environmental contamination. Nanotechnology has been utilized for dental applications in a few areas, including the field of prosthodontics with the advancement of nanobiomaterials as a helpful tool. Until now, there has been a dramatic expansion in examinations using nanotechnology for other dental applications. It is not too soon to consider, evaluate, and endeavor to shape possible impacts of nanodentistry. Nanodentistry will prompt productive and profoundly viable customized dental medicines. Nanotechnology is by all accounts where the world is going assuming innovation continues to progress, and competition basically ensures that technology will proceed. It will open a scope of opportunities or prospects for both the dental specialist and patient.

Over the past decade, the utilization of nanoparticles has become common in the development of numerous dental materials, since they offer a remarkable blend of properties. By the biggest application has been in dental composites, albeit a few exceptional glue structures containing nanoparticles have likewise been marketed. Each property has a basic length scale, and by utilizing building blocks less than the basic length scale, for example, nanoparticles—one can exploit the science of nanoparticles. An illustration of this is in light dissipation. Since nanoparticles have aspects well beneath the frequency of noticeable light (400–800 nm), they cannot dissipate that specific light bringing about incapacity to distinguish the particles by unaided eye. This has huge ramifications for controlling the optical properties of materials containing these particles. One more significant limitation to consider while utilizing nanoparticles is that due to their tiny size, they have a high surface region to volume proportion. Consequently, the exact control of the particle synthesis of the outer layer of nanoparticles becomes an essential part of quality and reproducibility of the nanoparticles.

This component is of significance since a critical component in nanotechnology is the capacity to intentionally control the group of the nanoparticles to offer the beneficial properties of the nanomaterial and a definitive exhibition of the materials into which they are consolidated.

Unmistakably, the different types of nanotechnology can possibly have a huge impact on society. Overall, it could be accepted that the use of nanotechnology will be gainful to people and businesses. Most of these applications include new materials which give profoundly various properties through working at the nanoscale, where new particularities are related with the exceptionally enormous surface area to volume proportions experienced at these aspects and with quantum impacts that are not seen with bigger sizes. The modern areas most promptly accepting nanotechnology are the data and communications area, including electronic and optoelectronic fields, food technology, energy technology and the clinical products, including a wide range of aspects of drugs and medication structures, diagnostics, and clinical technology, where the terms nanomedicine and bionanotechnology are now commonplace. Nanotechnology items may likewise offer novel opportunities for the decrease of environmental contamination.

Dr Saeed Farrokhpay is a Chemical Engineer with several years of experience in mineral & material processing. He obtained his PhD from University of South Australia in 2005. He is currently a Technical Consultant in Australia. He has worked for more than 20 years at mineral and chemical industries, universities and research centers around the world. Dr Farrokhpay has published more than 90 papers in high ranked journals and conference proceedings. He has also edited several technical and scientific books, and served as an editorial board member of several international scientific journals.

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